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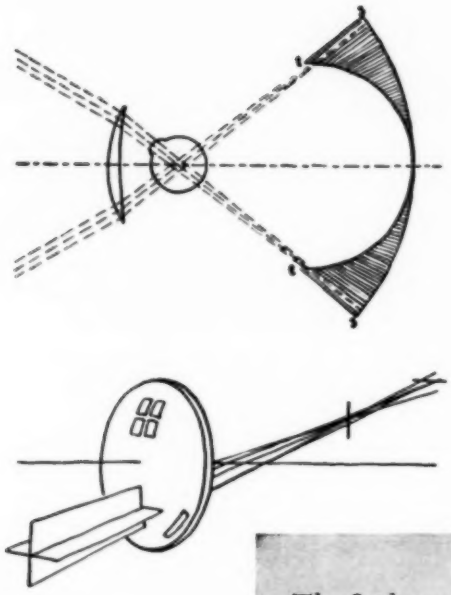

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KRYPTOK BIFOCALS	X	X	X	*	X	X	X	X	*	X	X	X	*
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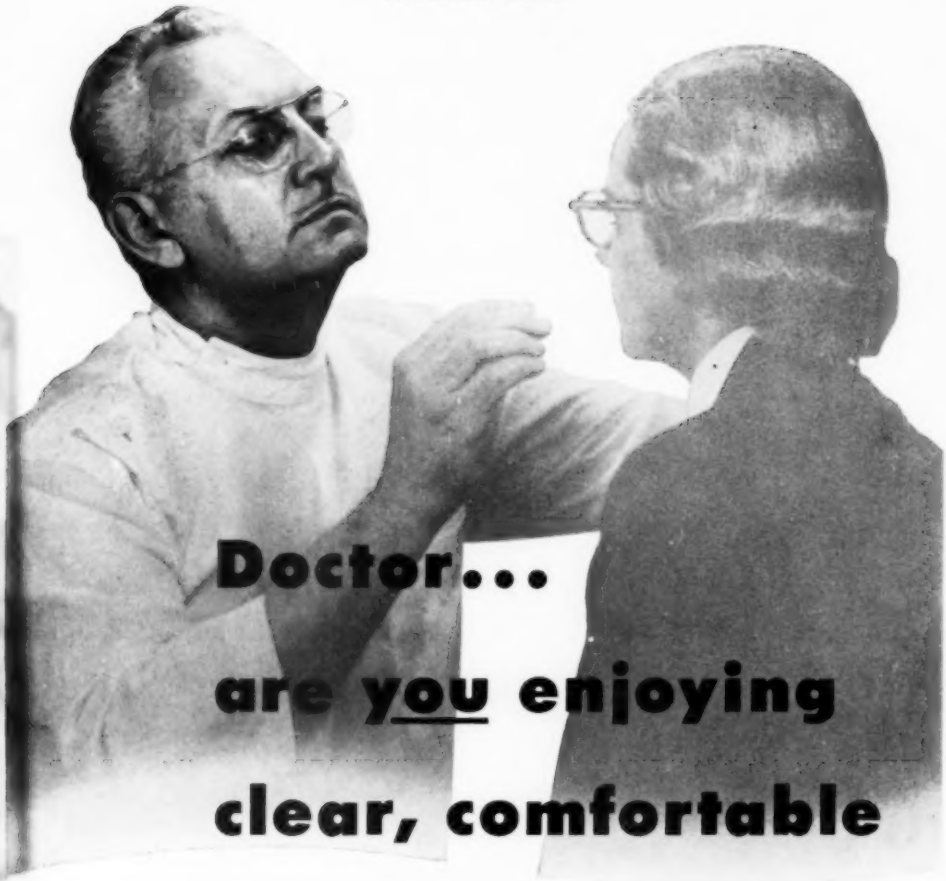

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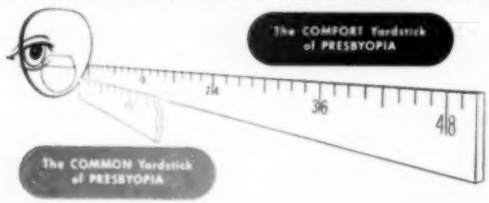

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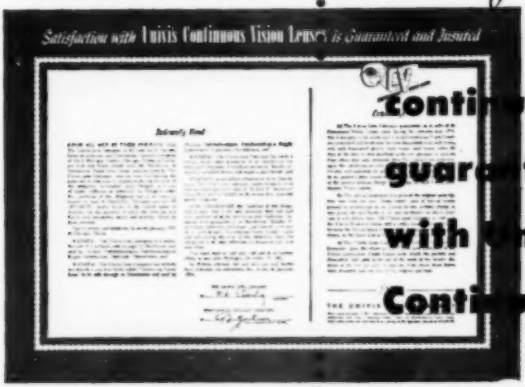

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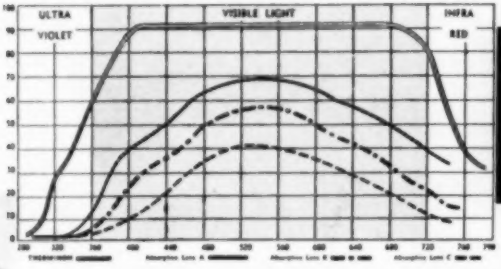

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42 mm.	4¼	4¼	4½	4½	
44 mm.	4½	4½	4¾	4¾	5
46 mm.	4½	4¾	4¾	4¾	5
48 mm.		4¾	4¾	5	

AO STADIUM FUL-VUE

Eye Sizes	*DBL and Temple Lengths*				
	18	20	22	24	26
40 mm.	4¼	4¼	4¼	4½	4½
42 mm.	4¼	4½	4½	4¾	4¾
44 mm.	4½	4¾	4¾	5	5
46 mm.		5	5	5	5¼
48 mm.		5¼	5¼	5¼	

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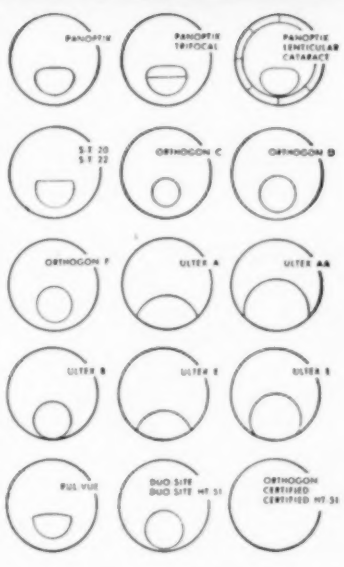

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"FLASHES" OF CLEAR VISION AND NEGATIVE ACCOMMODATION WITH REFERENCE TO THE BATES METHOD OF VISUAL TRAINING*

Elwin Marg†
School of Optometry, University of California
Berkeley, California

On rare occasions in clinical practice, a myopic patient is seen who relates that every once in awhile his usually blurred vision suddenly and briefly becomes beautifully sharp without glasses. This evanescent clarity, termed "flashes" of clear vision, cannot be elicited at will in the refracting room and demonstrated with a visual acuity test chart. The skeptical refractionist who wants to believe the patient, has no opportunity to measure this reported will-o'-the-wisp phenomenon.

What are these flashes? Do they occur as a result of a change of the refractive power of the eye (negative accommodation)? How much do they improve vision? These are some of the questions this investigation will attempt to answer.

BATES AND HIS DISCIPLES

Dr. William Horatio Bates, a New York ophthalmologist, was a maverick in his profession. In 1920 he published a book entitled "The Cure of Imperfect Sight by Treatment Without Glasses"[1] and started a school of vision practitioners (or educators) which is vigorous today.

Most of his claims and all of his theories have been considered false by practically all visual scientists. The quotations taken from throughout his book give, in substance, some of his principal ideas.

> [In retinoscopy] the observer is so near the subject that the latter is made nervous, and this changes the refraction. . . . This means that it must not be brought nearer to the eye than six feet; otherwise the subject will be made nervous, the refraction for reasons which will be explained later, will be changed, and no reliable observations will be possible.

Bates did not believe that the crystalline lens is the agent of accommodation because of two pieces of evidence. First, after four years of effort, he failed to find alterations in curvature of the anterior

*Read before the annual meeting of the American Academy of Optometry, New York, New York, December 10, 1951. For publication in the April, 1952 issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist. Assistant Professor of Optometry, Ph.D. Fellow, American Academy of Optometry. On military leave to the Aero Medical Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio.

surface of the lens during accommodation as indicated by changes in the size of the image of a reflected light source.§

His other evidence against lenticular accommodation was the occasional cases of apparent accommodation in aphakics.‡ It seemed evident to him that accommodation was effected by changes in the length of the eyeball.**

Let us return to quotations from Bates.[1]

> The obliques are the muscles of accommodation: the recti are concerned in the production of hypermetropia and astigmatism.
>
> Straining to see at the near point produces hypermetropia.
>
> Myopia produced by unconscious strain to see at the distance is increased by conscious strain.
>
> A person may have good vision when he is telling the truth: but if he states what is not true an error of refraction will be produced, because it is impossible to state or imagine what is not true without an effort.
>
> I may claim to have discovered that telling lies is bad for the eyes . . . [causing a change of refraction seen by retinoscopy].
>
> With such a [practically perfect or normal] memory of black, the retinoscope shows that all errors of refraction are corrected.
>
> Persons with normal sight have been able to look at the sun for an indefinite length of time, even an hour or longer, without any discomfort or loss of vision. . . . Even total blindness lasting a few hours has been produced. Organic changes may also be produced. Inflammation, redness of the conjunctiva, cloudiness of the lens and of the aqueous and vitreous humors, congestion and cloudiness of the retina, optic nerve and choroid, have all resulted from sun-gazing. These effects, however, are always temporary. . . . Some persons who have believed their eyes to have been permanently injured by the sun have been promptly cured by central fixation, indicating that their blindness had been simply functional.

In his book, Bates reported some experiments on animals, which have been criticized for their lack of proper techniques and a flouting of basic facts of anatomy and pharmacology.

Later editions of his book were published by his wife after his death in 1931. They were watered-down and more cautious.[6, 7] In the latter it was no longer claimed that imagining black could be used as a substitute for anesthesia in surgery, nor was it specifically stated that one should look directly at the sun. The original theories and most claims remained.

The fundamental principles of treatment are based on relaxation which, it is implied, is supposed to reduce to the vanishing point, all types of ametropia and ideally beget permanent emmetropia for its

---

§Many investigators including Helmholtz had observed the phenomenon and in more recent years Kirchhof[2] made dynamic recordings of this third Purkinje image. Allen[3] has developed the technique still further.

‡The rarity of these cases should be sufficient to make them suspect as a normal method of accommodation. Excellent evidence has been presented that there is no change in the refractive power of the eye in these cases.[4, 5]

**It is interesting to note that it would take about one millimeter change in axial length of the eyeball for each three diopters change of refractive power. Hence a youth accommodating 15 D. would shorten his globe by five millimeters. To the writer's knowledge, no corresponding anterior-posterior corneal movement has ever been reported.

fortunate follower. Relaxation is gained as follows:[7] 1. Resting the eyes. 2. Palming (excluding light and seeing maximum black). 3. Swinging (a gentle rotary motion of the trunk with the toes fixed). 4. Memory. 5. Imagination. 6. Flashing* or blinking (furtive glances and blinking from an eyes-closed position). 7. Central fixation (opposite of staring—looking all about an object). 8. Sun treatment (eyes closed, later open them but look downward).

Many other books have been published on the Bates method but few of them have offered anything original.[8-12] Most authors since Bates have leaned on him completely for scientific backing. In England, Price[13] followed the basic practices of Bates but did not adopt all of his theory. Price's book is moderate. While he does believe that strain is the basis of poor vision, he does not take sides in the accommodative theory by which poor vision is supposed to improve. Furthermore he made none of the extraordinary claims found in Bates' original book. One cannot help but feel that an honest attempt was made by Price to get to the basis of the reported phenomenon of flashing.

Mrs. Margaret Darst Corbett of Los Angeles, California, is a widely known, active and enthusiastic Bates practitioner who has developed a new group of teachers of the Bates method. Her two books[14, 15] show that she has experimented and adopted new techniques. The theory of Bates is at the core of her practices and she eulogizes it. A few quotations will illustrate her viewpoint.

> . . . vision is *nine-tenths* mental and only one-tenth physical.
>
> Near-sighted eyes need much done for them to bring them to normalcy. First they must have their tension relaxed so that the oblique muscles that belt the eye too tightly about the middle will let go. Then, the recti muscles must be strengthened so that they can flatten the eyeball for the distant focus; and in addition their endurance must be built up so that they can maintain their hold on the eyeball longer than a mere second or "flash" which most near-sighted eyes can get after just a little relaxation.
>
> Myopic eyes of clients get a flash—a touch of normal vision. Suddenly the oblique muscles let go and the recti contract, shaping the eyeball normally for a moment or two so that the entire panorama stands out perfectly just as with normal vision.

It would seem that in Mrs. Corbett's view, the "nine-tenths mental" part of vision acts to bring about changes in its "one-tenth physical" part.

> . . . carefully avoid squinting, or squeezing the lids, to clear vision. This is trick vision and injures the eyes. We want only normalcy, no tricks.
>
> Hold in the fingers of both hands a soft rubber ball. Squeeze it flat from front to back. Let it swell out round again. Then squeeze it around the middle so that it bulges long from front to back. Let it come round again. Watch the ball change shape from a lozenge to an eggshape. Do this repeatedly, rhythmically, saying aloud
>
> Squeeze it flat from front to back
> let it come round again
> Squeeze it long from front to back
> let it come round again

*It is to be noted that Bates did not use the term "flash" as it is used in this paper, to denote a sudden transient increase of visual acuity.

This doggerel by Mrs. Corbett presumably suggests the changing shape of the eyeball and through autosuggestion, a better control of ametropia is supposed to be gained.*

The intellectual giant of the Bates group is the well-known expatriate British author, Aldous Huxley. Whereas the books of Mrs. Corbett are best for learning the practice in cookbook fashion, the book of Huxley[16] is, without question, the best written and the most profound. It is relatively cautious in regard to the theories and to some of the claims of Bates.

Huxley had two reasons for writing this book. First as a debt of gratitude to Bates and to Corbett who, he believed, helped him to improve his own vision which was poor as a result of a bilateral keratitis acquired at the age of 16. His second reason was to "correlate the methods of visual education with the findings of modern psychology and critical philosophy." Huxley speaks thus:

> Vision is not won by making an effort to get it; it comes to those who have learned to put their minds and eyes into a state of alert passivity, of dynamic relaxation.
>
> This guess [The Bates theory of the mechanism of accommodation] may be correct; or it may be incorrect. I do not greatly care. For my concern is not with the anatomical mechanism of accommodation, but with the art of seeing—and the art of seeing does not stand or fall with any particular physiological hypothesis. Believing that Bates' theory of accommodation was untrue, the orthodox have concluded that his technique of visual education must be unsound. Once again this is an unwarranted conclusion, due to a failure to understand the nature of an art, or psychophysical skill.

Huxley, then, while showing respect for Bates, is not tied to his theories as most of the others appear to be. He seems willing to stand on improved visual acuity as the important demonstrable phenomenon in the Bates method.

ORTHODOX REACTION TO BATES AND DISCIPLES

Most visual scientists who read Bates or his disciples have immediately rebelled. The theories appear so wild, the evidence so poor, or lacking, in contrast to abundant and strong evidence by investigators of known scrupulous honesty and carefulness that the Bates techniques are thought to be unscientific.

This understandable reaction is seen in an answer to the Bates method by Sorsby,[17] a well-known British ophthalmologist. One by one he pointed out the flaws in the theories of Bates and criticized his experimental techniques with complete justification. Huxley's rebuttal was sharp and to the point.

> . . . Sorsby entirely fails to distinguish between two totally different things: the primary evidence confirming the existence of certain phenomena, and the secondary

*Not one to be limited to visual horizons, Mrs. Corbett now applies the Bates techniques to deaf ears.

evidence adduced to substantiate the hypothesis, in terms of which these phenomena are explained. The phenomena, which Bates sought to explain in terms of his unorthodox theory of accommodation, were those marked improvements in vision, which regularly followed the practice of certain educational techniques. The evidence for the occurrence of such phenomena can be supplied by thousands of persons who, like myself, have derived benefit from following the procedures in question, and by the scores of conscientious and experienced instructors who teach the method. If Mr. Sorsby really wanted to know about this evidence, he would get in touch with a few reliable teachers, ask permission to watch them at work and, if his own vision is defective, take a course of visual re-education. Instead of that he seeks to discredit the whole idea of visual re-education by denying the validity of the experiments used by Bates to support his explanatory hypothesis.

. . . Even if this secondary evidence were untrustworthy, even if the hypothesis supported by that evidence could be proved to be incorrect, this would make absolutely no difference to the facts which that hypothesis was originally intended to explain.

Duke-Elder,[18] in reviewing Huxley's book, was strong in condemnation of its theories but allowed the practice to a limited degree.

Whatever be the value of the exercises, it is quite unintelligent of Huxley to have confused their advocacy with so many misstatements regarding known scientific facts. It has been shown that the hypothesis upon which these methods of treatment are based is wrong; but Huxley, while admitting he is ignorant of the matter and unqualified to speak, contends that this is of no importance because the method works in practice and gives good results; it comes into the category of "art" not of "science." The argument is perfectly allowable, for in other spheres than medicine empirical methods have often produced effective results the rationale of which may be mysterious. The most stupid feature about his book, however, is that he insists throughout on the physiological mechanism whereby these exercises are supposed to work. It would at least have been logical if he had continued to allow the reader to assume that he was speaking in ignorance of anything except results. . . .

There would appear to be no doubt that these exercises have done Aldous Huxley himself a great deal of good. Every ophthalmologist knows that they have made quite a number of people with a similar functional affliction happy. And every ophthalmologist equally knows that his consulting-room has long been haunted by people whom they have not helped at all.

Duke-Elder concluded by saying,

For the simple neurotic who has abundance of time to play with, Huxley's antics of palming, shifting, flashing, and the rest are probably as good treatment as any other system of Yogi or Coué-ism. To these the book may be of value. It is hardly possible that it will impress anyone endowed with common sense and a critical faculty. It may be dangerous in the hands of the impressionable who happen to suffer from glaucoma or detachment of the retina. . . .

Lancaster, the late dean of American ophthalmologists, did not believe that any change takes place in the size or shape of the eyeball with exercise. In discussing eye exercises for the improvement of visual function, he said:[19]

If one studies the various publications with an open mind, searching for the things which will explain why the public wants this treatment, one will be forced to admit that buried in a mass of what to ophthalmologists seem foolish gestures and performances, best defined as hocus-pocus, there are sound and fruitful ideas. It is these that account for the survival and spread of the cult. It is certainly not foolish to believe that people can be taught to use their vocal organs in speaking or in singing, that they can be taught to play musical instruments, to dance, to skate and to play games, such as billiards or golf, and, as a result of teaching, can learn to perform better than they can without instruction and training. In the same way, the public argues, they should be instructed in the use of their eyes. They consult the ophthalmologist and are provided with glasses, but are given little information about the nature of their trouble or about measures which might help them to use their eyes successfully. Yet

they hear of some one who went to a follower of Bates and got plenty of instruction. There are many, very many, patients who do not want to wear glasses, who would go to almost any length to escape that fate.

. . . the . . . well-trained ophthalmologist is often ignorant of certain phases of the art and science of which he is supposed to be master. He is apt to make the mistake of arguing that because Bates' theory of accommodation is incorrect, his whole program is unsound. The history of medicine is a long list of tentative theories later proved to be erroneous, but the facts they tried to explain remain firmly established, though the theories are swept away.

It is often pointed out that Huxley's visual acuity has not improved in any extraordinary way. He admits that. The point is that he has learned how to use what he has to better advantage. It is not the primary retinal sensation that is improved; it is the neglected, but vitally important, cerebral part of seeing that has been trained.

Beach makes a distinction between two phenomena.[20] The first is the skill, for example, of the sailor who has been trained in the observation of marine objects. At discerning letters he is no better than the landlubber. This sort of facility, Beach claims, is acquired slowly and is permanent when once learned. Hence these skills are distinguished from fleeting episodes of visual improvement which is the second phenomenon.

An example of the second visual acuity phenomenon, according to Beach, is the World War II Air Force student pilots who passed the visual acuity examination as a result of visual training. Under the stress of flying many lost this ability and had to be grounded. Beach's distinction, however, may be of degree rather than kind. The mariner may have had many years of experience watching the horizon while the student pilot but a few months of special visual practice.

Beach does not believe that flashes of clear vision are the result of training in observation.

The essence of the popular courses for discarding glasses is of this transitory character. Devotees describe blinks of intensely vivid vision which they can elicit. They claim acuity at times of 20/10. They are impatient with ophthalmologists for neglecting this experience which to them is all-important. This keenness of vision may occur in one eye, and later be found to have shifted to the other eye. It may occur in both eyes. When binocular, one eye may predominate at one time, the other eye at a later time. This seems to place it on the ocular level. *To be accepted as entirely due to the improved cerebral interpretation of blurred retinal images, gain in sight should (1) be a permanent skill and (2) not be found to shift from one eye to the other.*

Beach believes that the eye may change its length in accommodation. His evidence consisted of 14 cases in which the visual acuity is compared without correction, "squeezing" with a one mm. pinhole and finally by both squeezing and a one mm. pinhole. "Squeezing" is an effort to increase visual acuity by narrowing the palpebral aperture and/or by increasing pressure on the globe similar to accidental squeezing which is fatal to cataract operations. In his experiments, about half the eyes (14) showed apparent improvement in visual acuity by squeezing but all of the cases of improvement were probably not significant, amounting to one line on the acuity chart. About 18 eyes showed

further improvement in visual acuity, some of questionable significance, when a pinhole replaced squeezing. If there should be an increase of visual acuity by squeezing after the pinhole is in place, it may be reasoned that the squeezing cannot further reduce the blur circles by narrowing the palpebral fissure but must change the state of refraction of the eye. This occurred in about 15 eyes but many of the changes were of questionable significance. Furthermore it is misleading as will be evident later to reason that a change of visual acuity must mean a change in the refractive state.

Beach concludes:

Presumably the globe has shortened. This does not determine whether the assumed shortening of the globe is due to compression by the lids, or to influence of the extra-ocular eye muscles. Nor does it indicate whether the action of the extrinsic muscles is squeezing according to my patient or relaxation of the obliques as maintained by Bates. It is customary to deride this notion of squeezing with the extra-ocular. Yet such a possibility is not wholly fantastic. Some such action has to be assumed to explain the squeezing in cataract patients which can take place even after the lids are paralyzed by akinesis.

Beach pointed out the great subjective value to myopes of seeing clearly without glasses.

It is customary to ridicule these sight-training exercises as a waste of time. The patient who attained the remarkable improvement by squeezing did not agree with this [probably Case 1, from 20/200 to 20/30]. He was delighted to be able to discard glasses in a number of common situations like recognizing friends on the street and reading signs. He valued it most in sailing. He pointed out that it is useful to be able to sail without having to keep wiping spray off glasses. It might be lifesaving to be able to recognize landmarks and pick up buoys if his glasses blew off. Such advantages are too real to be laughed off, and may account for some of the popularity of this system of training. Yet I understand he is likely to use his glasses much of the time.

In the discussion afterward Beach offered some strong words in defense of a refractive change causing flashes of clear vision.

I think there is a tendency to examine great numbers of patients and find out many of them do not do anything except improve their observation, whereas if we could devote a little time to some of these cases who do gain actual increase in acuity, and try to find out what makes them tick, we might get some sort of answer to the questions which are being asked by the persons who take these sight training courses. As a matter of fact, they are smart enough to know when they see vividly, as they do during what Bates calls central fixation, which is simply another name for these flashes that they get. They know if they see 20/10 vividly they are not getting a simple method of better distinguishing blurred images, and they are discounting statements that are made by oculists whom they feel ought to be stuffed and put in museums.

THE NEGATIVE ACCOMMODATION OF YVES LE GRAND

Le Grand[21] has presented evidence which indicates that some subjects are able to invoke accommodation in a negative direction. For example, a myope or an emmetrope made optically myopic with convex lenses can, in some instances, decrease his myopia with effort. Changes up to three diopters in a negative direction determined by skiascopy (taking ordinary accommodation to be positive in direction) were reported in five subjects. A summary of his results are seen in Table 1.[21, 22]

TABLE 1
RESULTS OF THE INVESTIGATION OF LE GRAND

Subject	Age	Refractive Error (Sph.)	Negative Accommodation	Lens Before Fixating Eye	Flash Visual Acuity
A	24-26	plano	2.50	+ 4.00	20/100 to 20/67
B	24-26	plano	2.25	+ 3.00	20/100 to 20/67
C	24-26	plano	2.25	+ 3.00	20/100 to 20/67
D	24-26	— 4.00	2.75	none	20/100 to 20/67
E	> 26	— 5.50	2.75	none	20/25*

*Subject E, skilled in the Bates method, can maintain this acuteness of vision several minutes in contrast to the other subjects who can hold their flashes for only a few seconds.

If these results could be confirmed,* they would demonstrate a mechanism whereby myopes trained by the Bates method obtain flashes of clear vision. Furthermore these results would lead one to expect that myopia of up to three diopters could be compensated for by negative accommodation much as hypermetropia may be compensated for by positive accommodation.

It is not to be implied that Le Grand agrees with the theories of Bates. His work merely indicates a possible mechanism which could account for some of the results claimed by Bates practitioners. Le Grand's evidence would not change the site of the accommodative mechanism from its generally accepted place, that of the crystalline lens and ciliary muscle.

At this point it seems clear that there should be an investigation which would attempt to confirm the findings of Le Grand, and determine if negative accommodation is the phenomenon which could account for the reported large increases in visual acuity which are claimed to be obtained by the myopic followers of Bates.

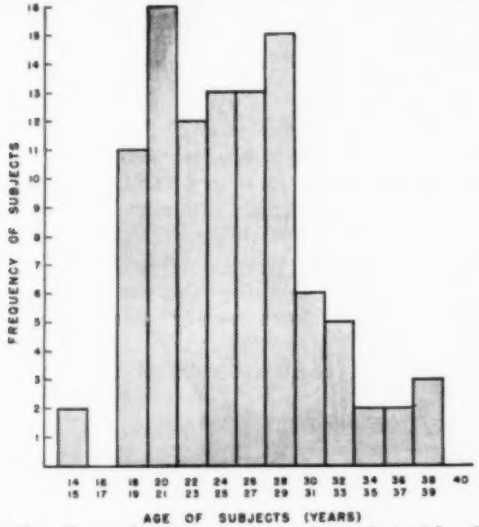
*There is some independent evidence which would seem to support Le Grand's finding of negative accommodation. The investigations of night ametropia of Otero and his collaborators[23, 24] have shown that the eye has about 1.25 D. more refractive power in total darkness than with distance fixation in light. The change of power is accommodative, i.e., the result of an increase in the curvature of the crystalline lens. Since he believes that accommodation is at rest in the dark and is therefore at its zero point, Otero uses the term "negative accommodation" for the range from what is generally considered 1.25 D. to zero accommodation. Whatever the merits of Otero's view, this is not negative accommodation in the sense used by Le Grand or in this paper. An eye examined in photopia has a refractive state which is its generally accepted zero point. Increase of refractive power in scotopia is *positive* accommodation. The refractive power of the eye must decrease from its generally accepted zero point to exhibit negative accommodation as defined here. Otero and his colleagues also claim to have demonstrated true negative accommodation of 1.0 to 1.5 D. in subjective experiments in which targets were viewed through a telescope. As yet there has been no confirmation of this phenomenon in their objective measurements of accommodation with Purkinje image photographs.

Also because of the definition of the zero point, the term "negative voluntary accommodation" used by Marg[25] does not apply here.

INCIDENCES OF FLASHES

The following experiment was performed in order to get some estimate of the incidence of those people who without regard to previous training or experience could obtain unusually clear vision, despite myopia.

One hundred clinical patients between the ages of 14 and 40 years were taken at random. The distribution of age is given in Figure 1. It



may be seen that the median age corresponds to that of Le Grand's subjects. They were refracted and a new prescription found. Those with a corrected Snellen acuity of less than 20/30 each eye as taken with a modern projector chart were rejected as subjects. The correction was put in a trial frame with a +3.00 D.S. add which blurred distance vision. Visual acuity was now taken at 20 feet with a Clason visual acuity meter. This instrument projects letters which may be varied in size while remaining in focus.

An occluder was held over the left eye and the subject was asked to read the letters as soon as he could without "squinting" or partly closing his eyelids. The size of the letters was increased until the subject could read more than half of the line presented. The same procedure was followed for the other eye and for both eyes together.

The subject was then instructed as follows:

Please try to see if you can clear up the blurred letters which you can now just make out while you are wearing these glasses. You can try anything you wish except

squinting your lids, looking by the edge of your glasses or moving closer to the chart. For example you may try such techniques as trying to relax while remaining alert, blinking, opening your eyes widely, looking to one side of the letters, making your eyes feel as if they were about to cross, or anything else you may think of within the restrictions mentioned. You will have about five minutes in which to develop some technique to make the letters clearer and, if possible, perfectly clear.

After about three minutes the subject was informally questioned about the techniques he had tried and his estimate of his success. As long as the subject believed that he could substantially improve his acuity he was allowed to keep trying.

Visual acuity was taken again, following the same procedure as formerly. If the subject showed a significantly high visual acuity with effort he was asked to return at another time when he would be examined by skiametry and with the coincidence optometer of Fry. If the acuity was not significantly improved, the subject was dismissed.

The limit of significantly high visual acuity was based on a study of Hirsch.[26] He found that for myopia of 3.00 D., the upper 95 per cent confidence limit was 20/130; that is, assuming normal distribution, only 2½ per cent of the subjects would be expected to show 20/130 or better. This is indeed a conservative limit since the Bates literature speaks freely of "perfect" sight and Le Grand found far better acuity in his subjects under conditions similar to those described below.

RESULTS

Of the 100 subjects with the +3.00 D.S. add to their distance correction, 99 could not show a visual acuity of 20/130 or better either before or after the period of attempted improvement. Many subjects thought they were improving their visual acuity but measurements indicated little or no change.

One subject, Miss R. D., a 19-year-old university sophomore, did show a remarkable transient increase in acuity. Her correction for maximum visual acuity was as follows:

R. E. —0.75 D.S. ⌒ —0.50 D.C. axis 155°, 20/25
L. E. —0.75 D.S. ⌒ —0.50 D.C. axis 75°, 20/25

Her visual fields were normal and her zone of single clear binocular vision was slightly narrow but otherwise normal. She had never taken any training to improve her vision either alone or under supervision.

When the new prescription was combined with a +3.00 D. add to both eyes in a trial frame, the subject had a visual acuity of R. E. 20/160, L. E. 20/145, B. E. 20/145. After about five minutes of attempting to see clearly, the subject was tested again, showing R. E. 20/33, L. E. 20/33. Before both eyes could be tested together, her vision returned to

the previous blurred state and no measurements could be taken by skiametry or coincidence optometry.

The subject returned in a week for another attempt but she could not flash again. Still another attempt was made a week later but without success. Hence it was not possible to investigate the mechanism of the original flash of clear vision.

Rather than speculate on the basis of flashes from this one uninformative case, it was decided to select a group of subjects who could flash at will so that any conclusions as to the mechanism of flashes could be based on the evidence of actual measurements.

ACCOMMODATION AND FLASHING

Two procedures were used to obtain subjects who could meet the necessary requirements for this experiment. The first was to place a classified advertisement in the personal column of *The Daily Californian*, a student newspaper. The notice read as follows:

> MYOPES! Do you have "flashes" of clear vision which you can MAINTAIN at will for at least several seconds without your glasses? If so, volunteer for a scientific investigation of this phenomenon. Telephone for appointments, University of California School of Optometry, AS 3-6000, local 301 or call at appointment desk, Optometry Bldg. Please mention this announcement.

It ran for three days with an average circulation of 17,000 copies per day. About 20 persons made appointments and were given a preliminary examination.

The other procedure used to obtain this specially selected population was to request of the various Bates eye training schools or studios in the San Francisco Bay area the opportunity to examine some of their successful students. The response ran the gamut from interest and cooperation to distrust and suspicion. Three subjects were thus obtained and their data will be given presently.

Of the 20 people who responded to the newspaper announcement, most were rejected for various reasons after a preliminary examination. Some apparently came solely out of curiosity. Others found it impossible to produce a flash at will or sustain it long enough for measurement to be made. Still others could show no significantly good acuity using the 95 per cent confidence level already mentioned for the ametropia concerned. A few could improve their vision by half closing the eyelids or putting pressure on the globe with a finger, but these were rejected. Two of the 20 did show a remarkable increase in acuity with effort and were accepted as subjects.

RESULTS

Mr. J. H. J., age 32 years.

History: In 1943 this subject took training for the improvement

TABLE 2

EXPERIMENTAL RESULTS

REFRACTIVE STATE DETERMINED FROM MEAN OF FIVE READINGS OF THE COINCIDENCE OPTOMETER OF FRY

Subject	Normal Vision D.	Flash Vision D.	Difference	t*	P	Visual Acuity — naked eye — Normal	Flash	Expected D. changes for the acuity difference	Age
Mr. J. H. J.						20/200	20/50	1.37	32
L. E. occluded	3.70	3.92	— 0.22	2.76	< .05				
B. E. fixating	3.84	3.71	+ 0.14	.78	< .05				
Miss S. S.	5.23	5.43	— 0.20	.54	< .05	20/200	20/70	1.12	19
Miss E. F.	5.77	5.56	+ 0.21	1.88	< .05	20/200	20/50	1.37	13
Mr. J. Y.	5.17	5.37	— 0.20	2.62	< .05	20/400	20/50	2.63	26
Mr. J. B.	7.14	6.87	+ 0.27	1.75	< .05	20/300	20/60	2.00	39

*Based on the difference between the means of two groups of five readings each. Four degrees of freedom.

of his myopia from a member and follower of the Optometric Extension Program. The subject believed that he still retained the ability to reduce his myopia with effort although not as well as originally. He claimed that he could read 20/25 without glasses at one time.

The following prescription was found to give maximum acuity:

R. E. —2.50 D.S. ⌒ —0.50 D.C. axis 67°, 20/20
L. E. —3.25 D.S. ⌒ —0.25 D.C. axis 170°, 20/20

Without lenses he exhibited 20/200 acuity in each eye and with both eyes together. With effort, visual acuity was increased to 20/50. The skiascope did not indicate any change of power before or after acuity was changed. Measurement was then made with the coincidence optometer of Fry. This instrument, which works on the Scheiner double pinhole principle, was introduced to the eye from the side through a half-silvered mirror which allowed a Snellen chart to be seen. Thus, the subject could make a vernier setting of the optometer images while fixating the Snellen chart. Five readings were taken with normal vision and the mean was found. Then five readings were taken with flash vision and they were averaged. The means and their differences are recorded in Table 2. The t test for the difference between means when the groups are correlated[27] showed that the value was not significant at the 95 per cent confidence level.

In order to see the effect of binocular relative to monocular fixation, both were used with this subject. The right eye fixating alone showed —0.22 D. (change in the myopic direction) which was not significant at the 95 per cent level. With both eyes fixating, the right eye measured +0.14 D. change (in the opposite direction) which is also not significant.* These two measurements were taken on different days.

From the increase of visual acuity alone one would expect a negative accommodation of about +1.37 D.

Miss S. S., age 19 years.

History: When she was 12 years old, this subject took Bates training and was able to get flashes easily. She stated that she could no longer get flashes as well as formerly.

The following prescription was found to give maximum visual acuity:

R. E. —4.75 D.S. ⌒ —0.50 D.C. axis 75°, 20/15
L. E. —5.00 D.S. , 20/15

*To avoid any possible confusion it should be stated that the minus sign is used to indicate *positive* accommodation which increases the power of the eye, in the direction of myopia. Contrariwise, the plus sign identifies *negative* accommodation which decreases the refractive power, in the hypermetropic direction. The signs represent the type of correction lens which would neutralize the accommodation.

Without lenses, the acuity was, R. E. 20/400 and L. E. 20/200. However, with effort (and initially using a "long swing") the subject was able to read 20/70 slowly. Skiametry of the right eye while the left eye fixated showed no change of refractive power from before the flash to after the flash had occurred.

On the coincidence optometer, five readings of the refractive state of the right eye were taken with normal vision and averaged. Then five readings were taken during flashes of clear vision and averaged. As may be seen in Table 2, the subject showed —0.20 D. change of refractive power with flashes (the minus sign signifies that the change is in the myopic direction). The increase in power was not statistically significant at the 95 per cent confidence level. To account for the increase of visual acuity a change of about +1.12 D. would have been expected.

Three subjects were obtained from the office of a practitioner of the Bates technique.*

Miss E. F., age 13 years. R. E. 20/400, L. E. 20/200, B. E. 20/200.

A subjective refraction yielded the following:

R. E. —5.50 D.S. ⌒ —0.50 D.C. axis 180°, 20/20
L. E. —5.25 D.S. . 20/20

With time and effort the visual acuity without glasses was raised to 20/50. Again there was no skiascopic indication of a change in the refraction.

The coincidence optometer indicated a change of only +0.21 D. as may be seen in Table 2. This change of power was not statistically significant at the 95 per cent level. It would have taken about +1.37 D. change to account for the increased acuity on the basis of retinal image sharpness.

Mr. J. Y., age 26 years. R. E., L. E. and B. E., 20/400.

A subjective refraction showed the following:

R. E. —4.75 D.S. ⌒ —0.75 D.C. axis 90°, 20/15+
L. E. —4.75 D.S. ⌒ —0.75 D.C. axis 90°, 20/15+

When this subject attempted to see clearly, he could read 20/50 with his naked eyes. No indication of a change in the refractive state was to be found with the skiascope. A change of —0.20 D. was found with the coincidence optometer as may be seen in Table 2. The change, as indicated by the minus sign, was in the myopic direction. The statistical significance of this change is below the 95 per cent level. The change did not attain the expected +2.63 D. if the increase of acuity is

*We are grateful to Mrs. Beatrice Clarke of the Berkeley Studio of Eye Education and to Mr. James Yandel for their co-operation in obtaining these subjects.

to be attributed to negative accommodation.

Mr. J. B., age 39 years. R. E. 20/400, L. E. 20/300. B. E. 20/300. This subject had a refractive error of the order of seven diopters of myopia but he was not available for a full subjective refraction.

The skiascope showed no change of refractive state when the subject attempted to read 20/60 and succeeded. The optometer showed +0.27 D. (change in the hypermetropic direction) without statistical significance at the 95 per cent level. This small value is not great enough to explain the large increase in visual acuity on the basis of a sharpening of the optical image on the retina. It would require about a +2.00 D. change in this case.

DISCUSSION AND CONCLUSIONS

From the results of the experiments reported here, one would not expect to find more than one person in a hundred capable of flashing without some special training.

It was further demonstrated that in all five specially selected subjects who could flash there was no change in the refractive power of the eyes which could account for the increase of visual acuity. Changes in the dioptrics of the eye ranged from +0.27 D. to —0.22 D. and none were statistically significant. Even the largest positive change (a decrease of refractive power) was not large enough to account for the great improvement in visual acuity (20/300 to 20/60).

The quality of the visual acuity was not as good as one would expect from the Snellen fractions given. It is frequently a slow process to get a flash and there was usually some stumbling over the letters. In the investigation of the five flashers, visual acuity was measured with a chart which was not familiar to the subjects. It was noted that familiar charts similar to the ones the flashers had practiced on gave better vision than 20/50.

Several questions arise regarding the increase of acuity exhibited by flashers. First what is the mechanism of the flash? All that can be said at this time is that the experimental evidence offered here indicates that there is no change of refractive power of the eye which is large enough and in the proper direction to provide a refractive basis for a flash. In other words, there is no evidence of a negative accommodation except perhaps in insignificantly minute and uncontrollable amounts.

It would seem that unless the phenomenon is attributable to extraordinary optical aberrations of the eye, for which there is no evidence, the increase in visual acuity exhibited by flashers must be central to the retinal image, i.e., in the physiological or perceptual image. The phenomenon seems similar to that of apparent accommodation in aphakia

where no change of refractive power of the eye has been found.[4, 5] It is likely that the perceptual image is improved by training and by the temporal accumulation of information of the visual apparatus during some of the ritual of swinging, blinking, etc. There is also presumably a better organization with time of the information which goes to make up the perceptual image.

Another question involves the retention of the skill of flashing. Most subjects were apologetic about the quality of their flashes, explaining that at one time they could clear up everything perfectly but at present the flashes were poor because of a lack of practice. Actually even the best subject could read no better than 20/50 with an unfamiliar chart. It appears that the Bates techniques are therefore limited both as to retention of the skill and to its ability to provide "perfect sight" even for short periods of time.

There are some further interesting points that should be mentioned. Although the visual acuity during a flash may not be better than 20/50, the subjective experience of the flasher is that he is seeing more clearly than he has ever seen with glasses that correct him to a visual acuity of 20/15. As Scholz[12] has said:

> *When you get a flash of perfect sight, you know it, it is a revelation.*
> Every flash convinces you more of the fact that there is nothing wrong with the eye itself, and this conviction, increasing patience and confidence, helps the treatment a good deal. [Italics mine.]

It is this strong introspective but psycho-physically erroneous evidence that helps keep the Bates technique alive.

Other interesting subjective phenomena are reported. The flasher may feel his flash of clear vision shift from its locus in one eye to the other or back again. He may feel a burning or stinging sensation in his corneas during flashes as if sand or wind had blown into his eyes. He may have illusions of form such as seeing a fan-like distribution of the letter he is trying to read. It merges and the letter becomes clear. These are but a few of the more generally reported phenomenological observations.

As a final word, the Bates and other similar visual training techniques should not be dismissed entirely. There are conceivable uses for them by those who will not or cannot wear optical corrections for their vision, or by those, such as Aldous Huxley where no optical device or orthodox treatment will help.

SUMMARY

The claims and counterclaims of Bates practitioners and orthodox eye specialists have been reviewed in detail. Particular attention has been

given to the report of negative accommodation by Le Grand which could provide a basis for some of the claims of the Bates school.

Two experiments were performed. A hundred clinic patients between 14 and 40 years of age were measured for visual acuity wearing their newly determined prescription combined with a +3.00 D.S. lens before each eye. Then after instructions on how to see more clearly followed by a short practice period they were again measured. Only one subject of the hundred demonstrated unusually good transient acuity (a flash) but she was unable to maintain it or repeat it for measurement of refraction. This experiment indicated that "flashers" (those who can obtain remarkably large transient increases in visual acuity) are uncommon. The next experiment consisted of five specially selected subjects who could flash. Some of them were undergoing Bates training at the time. Visual acuity was improved from around 20/200 to 20/50. The refractive state of the eye was measured by skiametry at one time and with the coincidence optometer of Fry at another. No change in power was found by skiametry from normal to flash vision. The optometer indicated changes of —0.22 D. to +0.27 D. none of which were significant at the 95 per cent confidence level. For the changes in acuity to be attributable to negative accommodation, the dioptric change would need to be from about plus 1 to 2.5 diopters, depending on the subject.

The finding of negative accommodation by Le Grand could not be confirmed.

It is suggested that the Bates method improves the perceptual image by training interpretation of blurs, and by the accumulation of visual information during the relatively long time required for the eliciting of flashes.

The introspective feeling not borne out by measurement, of a clarity during flashes greater than that experienced when allowed to have 20/15 vision with glasses is an important factor in explaining the popularity of the Bates school.

The Bates method and other similar visual training techniques have conceivable uses, but they are no substitute for helpful optical correction of the eyes.

Since this paper was written, it has been brought to the writer's attention that an article entitled "Variable Acuity" by James R. Gregg has appeared in an unabstracted journal (Jour. Amer. Optom. Assn., 18, 432-435, March, 1947). The results of this paper essentially agree with the data presented here in relation to the increase of visual acuity and the lack of change of accommodation as measured by skiametry. Two of the three subjects had a very low degree of myopia and were able to flash to 20/20. The third subject who was a myope of about —4.50 D. could flash only to 20/50.

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THE BIOPHYSICS OF CORNEAL SCATTER AND DIFFRACTION OF LIGHT INDUCED BY CONTACT LENSES*

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PART I

I. INTRODUCTION

The visual phenomena of haze and haloes that arise because of the scattering and diffracting properties of the ocular dioptric system form the general province of this investigation. The physiological processes underlying this optical behavior is its more particular area: and it is specifically concerned with the manner in which the use of contact lenses influences their appearance and development.

These or related phenomena occur spontaneously in conditions of which corneal edema is a symptom. The colored haloes seen around bright lights by glaucoma patients are only too well known. Their occurrence in cases of essential corneal edema[1] has been described. They have been observed as a result of exposure to ultra violet radiation,[2] as well as to atmospheres of high CO_2 partial pressure.[3] They have been induced following instillation into the conjunctival cul-de-sac of certain agents such as 2 per cent silver nitrate or the alkaloid erythrophleine.[4] Recently, the subjective appearance of haloes of blue color among workers exposed to atabrine also has been reported.[5] Under suitable conditions even many normal people are able to distinguish these luminous spectral rings surrounding intense sources.[6] The dynamic pattern, the kinetics of their development when contact lenses are worn and their recession when the lenses are removed may be, therefore, of interest in fields other than that concerned with their use as visual aids.

At the present time,‡ almost the entire momentum of practical development in the contact lens field is directed toward the elimination

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‡A skillfully written account of the early history of contact lens development by Ida Mann is to be found in "The Transaction of the Ophthalmological Society of the United Kingdom" (1938), Vol. 58 (1), p. 109.

of the disturbing scatter and diffraction phenomena which have come to be loosely characterized as Sattler's veil.[7] The relative ease of manipulation, and of introduction of chemical and physical variants, may give the experimental use of these lenses significance for the study *in vivo* of ocular physiology in particular, and cellular physiology in general. This is all the more so since the exquisite discriminating ability of the living organ, the eye, of which some of these cells form the dioptric tissues, can be used for measurement.

II. WORKING HYPOTHESES

Hypotheses in explanation of these optical effects may be concerned with various levels of the total phenomena and be based on corresponding phases of the total physiology.

A. *The Chloride Shift Hypothesis*

This is concerned with the basic processes by which the cellular elements involved change their optical properties sufficiently to produce these effects. It is at once the most fundamental and the most difficult approach. At present we can offer only a physiological analogy, that of the chloride shift in erythrocytes when the pH varies.

As the pH decreases, with increase in CO_2, base (K^+) is split from Hb and combines with H_2CO_3 to form $KHCO_3$, which dissociates into K^+ and HCO^-_3. HCO^-_3 leaves the erythrocytes and is replaced by Cl^- from the plasma. The osmotic pressure of the erythrocytes with respect to the plasma increases, since the net concentration of K^+ within the cell is not appreciably altered, and the cell absorbs water and swells. The process is reversible,[8] osmotic pressure of the cells varying inversely with the base binding capacity of the hemoglobin and, therefore, with its acidity. The acidity of hemoglobin varies directly, however, with its degree of oxygenation. Osmotic pressure, water content and cell volume vary inversely, therefore, with the degree of oxygenation or directly with the degree of anoxia. If such a mechanism exists in the cornea, osmotic equilibrium will depend on the rate at which carbonic or other acid accumulates as compared with that at which oxygen is supplied.

The cornea is believed to possess an external respiratory mechanism. O_2 normally diffuses inward while CO_2 diffuses outward. If a contact lens should interfere with normal gaseous exchange or with acid-base balance or both in such a way as to produce a relative anoxia, then the corneal elements might behave like erythrocytes, providing an ampholyte resembling hemoglobin were present in these structures. Since the corneal elements are transparent, a change in refractive index might result, accompanied by scatter and diffraction effects such as those

observed. If such a mechanism exists, then a difference in buffer capacity of contact lens solutions, and consequently in their CO_2 uptakes, should result in a corresponding difference in the rate at which the optical disturbances develop.

B. *The Osmotic Pressure Hypothesis*

At another level, involving the physiology of fluid exchange of the cornea, Professor Kinsey[9] has proposed a mechanism* based on the Cogan-Kinsey theory of corneal water balance.[10] According to this theory, water is supplied the cornea from the perilimbal capillary plexus. It is extracted across the endothelium by the hypertonic aqueous and across the epithelium by the hypertonic lacrimal fluid.** Reduction in the rate of outflow for any reason results in increased hydration of corneal tissue, since this is the most hydrophilic of all tissues.[11] According to the osmotic pressure hypothesis, hypertonic solutions contained between cornea and contact lens are rapidly diluted by water diffusing out of the cornea. The process continues until the contained fluid becomes isotonic with corneal interstitial fluid. The normal osmotic gradient then disappears and the cornea continues to turgesce to the limit of its hydration capacity. If hypotonic solutions are used, water diffuses into the cornea and is replaced, we suppose***, by lacrimal fluid until isotonicity with plasma is established. The course, thereafter, depends on the previous degree of hydration. We suppose, further, that imbibition induces changes in the relative refractive indices of the corneal elements responsible for the optical effects.

If this is the mechanism, then the kinetics of the optical phenomena should follow a definite pattern. Hydration should occur from the first moment a lens is inserted with hypotonic solution, and the optical changes should become rapidly apparent and proceed at a mean rate inversely proportional to the tonicity of the contained fluid. If some form of lag or threshold phenomenon is involved, then the first appearance of the optical effects, even with hypotonic solutions, may be increasingly delayed with increasing tonicity. They may become apparent only when turgescence reaches some liminal value. Their mean rate of development should decrease to a limiting value attained with an isotonic solution. For increasingly hypertonic solutions the kinetic patterns should be intrinsically identical but increasingly delayed by the

*The explanation based on this mechanism we call the Osmotic Pressure Hypothesis.

**Krogh[12] has found that the lacrimal fluid, as secreted, is isotonic with plasma and, therefore, with corneal interstitial fluid. Evaporation from the thin pre-corneal film presumably increases the osmotic pressure. The effective lacrimal film is probably isosmotic with 1.4% NaCl and 2.0% $NaHCO_3$.

***This is a reasonable supposition, since the volume of the contained fluid remains practically constant throughout.

interval required for dilution to isotonicity and for corneal hydration to liminal turgescence. After isotonicity is reached, further drainage should cease unless mechanical circulation of lacrimal fluid is a significant component of the total drainage kinetics. If two such components contribute to the drainage of the contained fluid, then the point of isotonicity on a drainage curve should resemble a point of discontinuity. The prominence of such singular points will depend on the relative contribution, to the total drainage, of the component due to the fluid exchange across the cornea along osmotic gradients. If the corneal components are relatively small, then the presence of such singular points may be masked by the experimental variability in the lacrimal component, which proceeds mechanically at a constant or nearly constant rate. The kinetics of the optical changes and of drainage should provide a test of this hypothesis.

C. *The Invasion Hypothesis*

At the level of the vascular response to mechanical irritation we have considered an hypothesis presupposing an invasion of the cornea by white blood cells extravasated from the perilimbal vessels. Mayou[13] has shown that neutrophils appear with great rapidity when the conjunctiva is irritated. Elliot[14] has indicated that these elements invade the cornea in large numbers in acute glaucoma, and Duke-Elder[15] has found an invasion of esosinophils in animal eyes exposed to ultra violet radiation. Fischer[16] has found such corneal infiltration when rabbits' eyes have been bathed in various chemical agents. Should these elements invade when contact lenses are worn and should they have an index of refraction sensibly different from the other corneal elements, they may act as the scattering and diffracting bodies.

The most direct test of this hypothesis is the histological demonstration of their presence within the optical zone of the cornea. Such studies are practically confined to animal eyes, and before the results may be considered valid the occurrence of the primary phenomena of haze and haloes in their eyes must be demonstrated. In human eyes, the hypothesis may be tested by studying the effect of a variable pupil on halo brightness. If invasion occurs, then an increasing population density gradient of diffracting bodies should extend centrifugally over the cornea, and halo brightness which is directly proportional to the total number of effective particles[17] should increase at a rate greater than that at which pupillary area is increased. If the particles are uniformly distributed over the cornea, halo brightness should increase at the same rate as pupillary area. Such a uniform increase might occur if the chloride shift or osmotic pressure hypothesis applied.

III. BIOPHYSICAL DETERMINATIONS

The histological complexity of the cornea suggests the possibility that more than one type of microscopic element may be involved in these phenomena. Their diverse metabolic behavior suggests, further, that if more than one type is involved, each may make its contribution to the total optical pattern at a characteristic rate, and differences of phase should be detectable. In addition to testing the three hypotheses already mentioned, the primary purpose of the investigation is to determine, on biophysical grounds, the unitary, binary or multiple nature of the scatter and diffraction systems and the relations between them. These determinations include: (1) computation of particle size from halo diameter measurements; (2) computation of population density from halo brightness and particle size; (3) evaluation of the order of magnitude of the scattering particles from determinations of differential scattering; and (4) a study of corneal changes entoptically observable, and of the manner in which their kinetics are related to those of the other optical phenomena. All of these determinations form a framework, developed in vivo, for an extensive histological and histochemical study which this investigation has begun.

IV. EXPERIMENTS

A. *Corneal Scatter Kinetics*

Our first concern was with the development of a sensitive photometer for the purpose of measuring the changes in the scattering of light from the cornea as well as from some of the other ocular media. Some interesting and probably very effective instruments for this or similar purposes have been described by Dekking[18] and Goldsmith,[19] but these were not available in this country. We were fortunate in obtaining an old, but excellent, Gullstrand slit lamp and proceeded to adapt this instrument.†

1. *Apparatus*

Essentially the completed instrument consists of a conventionally mounted slit lamp called the "illuminator" and an electronic microphotometer called the "detector." The illuminator projects a bright beam of light into the eye. The detector measures the amount of light returned from the illuminated region of the eye that lies in its field of view.

The optical scheme is shown in Figure I. The radiating source (1) is a 6 volt, 18 ampere, ribbon filament lamp maintained at nearly constant brightness. Light passes through a set of condensers (2) that illuminate a variable slit (3) whose image is projected by the lens (7) in the ocular region to be measured (8). The detector consists of a 48mm. micro Tessar objective (10), a beam splitter (11), a visual ocular (12) equipped with parallel micrometer hairs (13), and a phototube ocular (15) equipped with parallel micrometer slit jaws (16).* Cross hairs and jaws are origi-

†The Gullstrand slit lamp was kindly placed at our disposal by Dr. J. P. Macnie of the Institute of Ophthalmology of the Presbyterian Hospital in New York City.

*The detector is drawn as though turned through 90 degrees on its axis to bring the phototube ocular assembly into the plane of the drawing. Actually it stands vertically above this plane.

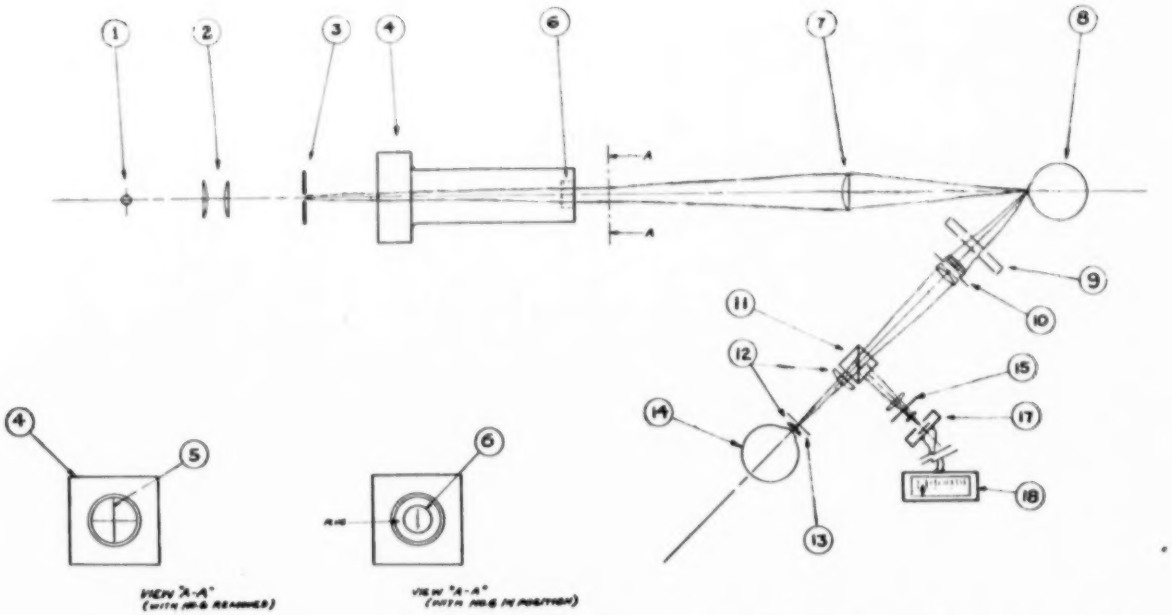


Fig. 1. Plan of the optical system of the microphotometer: 1. Light source. 2. Condenser. 3. Slit jaws. 4. Filter rack. 5. Cross hairs. 6. Ocular micrometer (occasionally used). 7. Projection lens. 8. Subject's eye. 9. Filter (used occasionally). 10. Microscope objective. 11. Beam splitter. 12. Visual ocular. 13. Micrometer wires. 14. Observer's eye. 15. Phototube ocular. 16. Slit jaws (micrometer). 17. Phototube. 18. Galvanometer.

nally carefully adjusted and set by means of a cathetometer, so that equivalent micrometer settings give, in general, equivalent separations and expose identical fields.** If the visual and phototube oculars are optically matched as they are in our instrument, then equal separations obtained by equal micrometer settings expose equal fields. The visual field serves, therefore, as a guide in positioning the detector. The multiplier phototube is a selected R.C.A. (1P21) and forms part of a standard assembly utilizing dry cell power supply and a sensitive and fast galvanometer (18).***

The tubular stop is equipped with cross hairs (5), (view A-A), placed in the anterior focal plane of the projection lens (7) for controlling the subjects' fixation, while the high sensitivity of the detector permits the use of a No. 1 Wratten neutral density filter which, when placed in the filter box (4), serves the dual purpose of moderating the slit lamp beam and acting as an internal reflecting surface in the production of corneal reflexes which, picked up visually in the detector, have proven most useful in positioning the beam reproducibly.

The physiognomical variability among subjects, the high curvature of the cornea and consequently rapid variation in the angle of incidence of a beam of light with slight movements, and the concomitantly rapid variation in the Fresnel ratios[20] between reflected and refracted light impose rather rigid limits within which subjects must be reproducibly positioned relative to the photometer. For this reason adequate targets for fixation and rigidly mounted individual bites for head positioning are provided. Furthermore, the duration of a single run may be as long as eight hours and since more than one subject is generally measured in a single day, the photometer is equipped with suitable controls for reproducibly positioning both the illuminator and detector.

Of equal importance with precise positioning of the instrument and subject is the standardization of slit lamp brightness and detector sensitivity. A photometric standard ordinarily used with a Macbeth illuminometer serves this purpose.[21]

2. *Procedure*

Experience indicates that the instrument should be standardized at the beginning of each day's work and checked at the end of the day. All measurements were made after the detector sensitivity had been adjusted to a fixed level. This was accomplished by pointing the detector at a modified reference standard of the illuminometer. The modification consists of placing a ground glass plate and a neutral density filter before the aperture of the conventional unit and stopping down the diffuse source so produced to a narrow slit by means of fixed jaws. This arrangement places the field stop[22] of the entire system in the focus plane[23]. It eliminates any error that might have been introduced, if the clear filament lamp of the reference standard were used alone, by even slight variation in the setting of the phototube slit jaws, which would otherwise act as the field stop. Current for the reference standard lamp is supplied by dry cells and indicated by a milliameter, both housed in the illuminometer control box. The entire reference standard, so arranged, is mounted in an adapter which assures reproducible positioning before the detector.

The sensitivity is actually set when a predetermined deflection of the galvanometer (Fig. I #18) is obtained by controlling the photo-

**This general case is indicated in the drawing.

***This assembly is regularly furnished by the Farrand Optical Company in New York City.

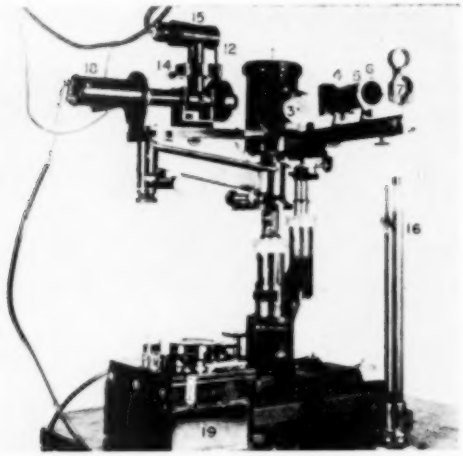


Fig. II. Detector and Macbeth photometric standard arranged for standardizing phototube sensitivity.

tube input. Figure II is a picture of the detector and illuminometer arranged for this purpose. This reference standard, which is used daily, is checked from time to time by comparison with a second and similar standard reserved for this purpose. We have found it to maintain constancy if carefully manipulated. When the sensitivity has been set and the reference standard removed, the detector is positioned

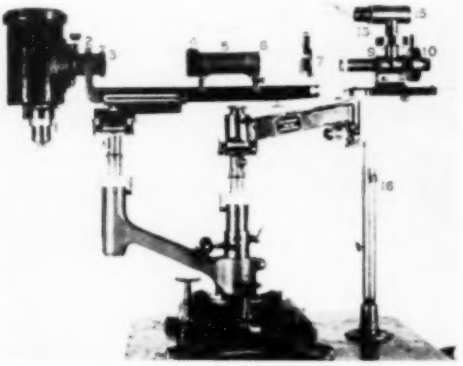


Fig. III. Instrument aligned for standardizing slit lamp brightness.

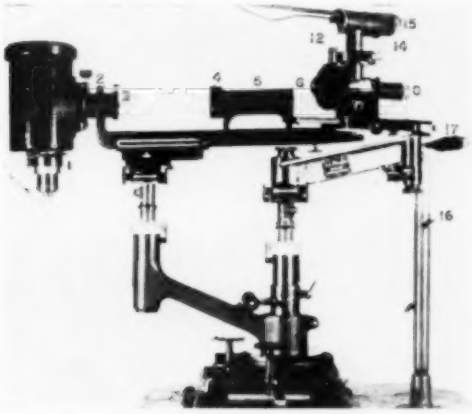


Fig. IV. Instrument in standard position.

coaxially with, and pointing at, the slit lamp beam as shown in Figure III. With a #5.0 neutral density filter in the filter box (Fig. I #4), the current to the slit lamp is adjusted until a predetermined standard deflection of the galvanometer is obtained. When the standardization of sensitivity is completed, a #1.0 filter replaces the #5.0 filter, and the instrument is arranged as indicated in Figure I and pictured in Figure IV. This we call the standard position. Figure V is a detail photograph of the detector.

Figure VI illustrates appearances in the visual field as seen during a measurement of the left eye of a human subject. In A of this figure the luminous corneal prism, the parallel micrometer wires and the positioning needle, which moves vertically in the field on a micrometer screw, are shown for a naked cornea. The fine white circle is a dim corneal reflection of the projection lens, visible only because of light scattered by the lens mount. The vertical white line within it is due to diffraction around the vertical cross hair (Fig. I #5). A lateral movement of the entire instrument to the subject's left brings this reflection to the area of the corneal prism. Here it becomes brilliant by specular reflection. A movement to the subject's right brings the small white reflex, shown in B, into view. If the movement continues, this reflex disappears and a new one, as indicated in C, appears. The small reflex shown in B is due to an internal reflection, since it vanishes when the filter is removed. The standard position used is shown in A.

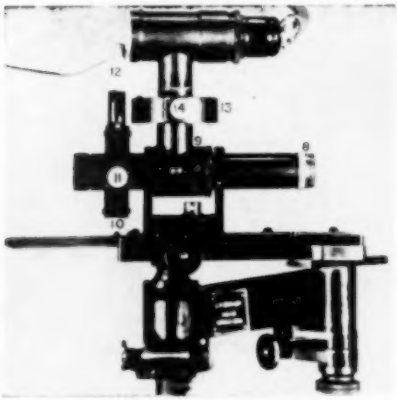


Fig. V. Lateral view of detector.

It is reached by a slight movement to the right of the position represented by B. The appearance with a contact lens in place is shown in D. The vertical displacement of the circular reflex is due to the gravity lag of the contact lens. A slight shift of the instrument to the subject's right would bring the small white reflex into view.

Measurement indicated that the corneal scatter of a given subject remained constant to within 2 per cent throughout a single day at normal operating illuminator brightness. For a tenfold increase in brightness, the scatter measurements remained constant to within 5 per cent for a single day, and to within 8 per cent from day to day. Table III, IV and V give the data for our subjects. In general, a single run consisted of an initial determination of scatter from the naked cornea. Four exposures of the detector were made in rapid

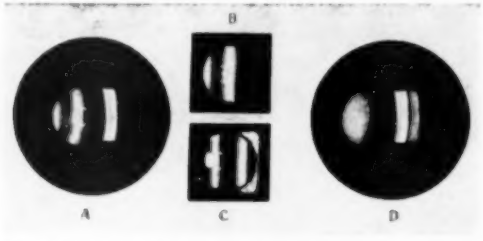


Fig. VI. Visual fields of a human eye in the photometer.

TABLE I

Composition of Solutions at Room Temperature (22°C. to 25°C.).

Series	Solution No. 1* (milliliters)	Solution No. 2** (milliliters)	Water (milliliters)	Osmotic Pressure*** Coefficient (computed)	Osmotically**** Equivalent $NaHCO_3$ Solution (concentration %)
Ringer's	50.0	0.0	50.0	0.33	0.50
	66.7	0.0	33.3	0.66	1.00
	100.0	0.0	0.0	1.00	1.50
Isosmotic	50.0	50.0	0.0	1.00	1.50
	33.3	66.7	0.0	1.00	1.50
	0.0	100.0	0.0	1.00	1.50
	100.0	0.0	0.0	1.00	1.50
$NaHCO_3$	0.0	12.5	87.5	0.08	0.13
	0.0	25.0	75.0	0.16	0.25
	0.0	50.0	50.0	0.33	0.50
	0.0	66.7	33.3	0.66	1.00
	0.0	100.0	0.0	1.00	1.50

*Solution No. 1

NaCl	10.00 gms.
CaCl	0.17 gms.
KCl	0.10 gms.
$NaHCO_3$	0.17 gms.
H_2O	1000. ml.

All salts weighed as anhydrous.

**Solution No. 2

$NaHCO_3$	15 gms.
Water	1000 ml.

***Osmotic pressure coefficient $= \frac{\text{Osmotic pressure of Solution}}{\text{Osmotic pressure of Solution No. 2}}$

****All the coefficients indicated are approximate, subject to the condition that an activity coefficient of 1.00 was assumed for all the solutions.

succession.† The mean, g_o, of the corresponding galvanometer deflections was assigned a value of 10.0 per cent. This defined an arbitrary scale of brightness to which subsequent determinations were converted by a proportionality factor k such that $k = \frac{10}{g_o}$. A contact lens filled with the solution to be studied was then quickly inserted and another determination made. The difference between these determinations was due to added scatter by the contact lens and contained solution, as shown in D of Figure VI.

Additional determinations of relative brightness were made at about one-half hour intervals over a period of about six hours.‡

†For the constancy measurements of the naked cornea, nine exposures were made for each determination.

‡Runs with solutions of very low tonicity usually lasted considerably less due to discomfort.

TABLE II
Freezing Point Depressions of Contact Lens Solutions.

Series	Concentration $NaHCO_3$%	Osmotic Pressure Coefficients (Computed)	Freezing Point Depressions Grouped According to Computed Osmotic Pressure Coefficients 1.00	0.66	0.33	Osmotic Pressure Coefficients (Observed)
			Degrees Centrigrade			
(1)	0.0	1.00	0.642			1.05
Ringer's	0.0	0.66		0.440		0.72
	0.0	0.33			0.245	0.40
(2)						
Isosmotic	1.0	1.00	0.629			1.03
Ringer's	0.5	1.00	0.639			1.05
+ $NaHCO_3$						
(3)	1.5	1.00	0.610			1.00
$NaHCO_3$	1.0	0.66		0.376		0.62
	0.5	0.33			0.175	0.29

After the last determination the contact lens was removed and the scatter from the naked cornea was again determined. The difference between this final pair of determinations was generally equal to the difference between the initial pair. The change in scatter of the solution remained practically constant, therefore, throughout a run, even though it collected an appreciable amount of debris. For practical purposes, therefore, the kinetics pattern obtained with the contact lens in place was that of corneal scatter alone.

Three series of solutions were used. They were chosen to distinguish between the effect of buffer capacity and osmotic pressure.

(1) *Solutions with negligible buffer capacity.* The members of this series consisted of solutions of Locke's Ringer's at dilutions computed to be isosmotic with $NaHCO_3$ solutions of 0.5%, 1.0% and 1.5%. This series was designed to test the importance of osmotic pressure alone, always providing that considerations of specific ion effects or ionic strength remained negligible.

(2) *Solutions all computed to be isosmotic with 1.5% $NaHCO_3$ but of variable*

TABLE III
Corneal Scatter Constancy for a Single Day with Normal Operating Illuminator Brightness.

Subject	B. D. Time	g_o	J. E. Time	g_o	H. K. Time	g_o
	0 hrs.— 0 min.	7.7	0 hrs.— 0 min.	10.0	0 hrs.— 0 min.	5.6
	0 hrs.—46 min.	8.2	1 hrs.— 7 min.	10.1	1 hrs.—28 min.	5.8
	0 hrs.—52 min.	8.1	1 hrs.—44 min.	9.9	2 hrs.—58 min.	5.9
	3 hrs.—46 min.	7.8	1 hrs.—55 min.	10.1	3 hrs.—52 min.	5.9
	5 hrs.—40 min.	8.1			4 hrs.—27 min.	5.9
	6 hrs.—58 min.	8.1			5 hrs.—14 min.	5.7
	7 hrs.— 2 min.	8.1				
Mean		8.0		10.0		5.8
a. d.		0.16		0.08		0.10
Precision		2%		1%		2%

TABLE IV

Corneal Scatter Constancy for a Single Day with Ten Times Normal Illuminator Brightness.

Subject	B. D.		J. E.		H. K.	
	Time	g_o	Time	g_o	Time	g_o
	0 hrs.— 0 min.	80.0	0 hrs.— 0 min.	47.4	0 hrs.— 0 min.	59.3
	0 hrs.—52 min.	79.6	0 hrs.—30 min.	52.1	1 hrs.— 0 min.	55.2
	2 hrs.—22 min.	71.4	1 hrs.—17 min.	53.8	1 hrs.—45 min.	59.4
	2 hrs.—57 min.	70.2	3 hrs.— 7 min.	52.8	2 hrs.—30 min.	55.3
			3 hrs.—45 min.	53.2		
			4 hrs.—28 min.	61.0		
			5 hrs.— 7 min.	56.1		
			6 hrs.— 4 min.	48.9		
Mean		75.3		53.2		56.6
a. d.		4.4		2.7		2.8
Precision		6%		5%		5%

buffer capacity, equivalent to the buffer capacities of 0.5%, 1.0% and 1.5% $NaHCO_3$. This series was designed to test the importance of buffer capacity alone for a fixed osmotic pressure. These solutions consisted of appropriate mixtures of $NaHCO_3$ and Locke's Ringer's, as indicated in Table I.

(3) *Solutions variable in both buffer capacity and osmotic pressure.* These were solutions of $NaHCO_3$ of 0.125%, 0.25%, 0.5%, 1.0%, 1.5% and 3.0%.

The buffer capacities of osmotically equivalent members of series (2) and series (3) were experimentally checked at 37°C. in a closed system ventilated by bubbling N_2 through the reaction mixture at constant pressure. It consisted of a stoppered glass reaction chamber suspended in a constant temperature bath. Through apertures provided for the purpose, a burette, a frittered glass bubbler, a glass and calomel reference electrode, an outlet equipped with a soda lime guard tube, and an automatic stirrer were introduced in an air-tight fashion into the reaction chamber. The necessity for such an arrangement becomes evident from a study of the behavior of a $NaHCO_3$ solution. The total reaction can be considered as an hydrolysis followed by the splitting of H_2CO_3 and the escape of CO_2. It can be indicated as:

$$NaHCO_3 \rightarrow Na^+ + OH^- + CO_2\uparrow$$

The rate of the hydrolysis is actually controlled by the rate of splitting of the H_2CO_3 formed. This is a slow reaction catalyzed in vivo by carbonic anhydrase. In a normal atmosphere containing CO_2 the hydrolysis proceeds slowly to equilibrium from an initial pH of about 8.3 to a final pH of about 9.3 in a matter of hours. With our arrangement equilibrium could generally be reached in about an hour. We proceeded to titrate with HCl without waiting for equilibrium, since this most closely resembled the condition that prevailed in the contained solutions into which CO_2 is presumed to diffuse from the cornea from the first moment of insertion of the lens. The results in-

TABLE V
Corneal Scatter Constancy from Day to Day with Ten Times Normal Operating Illuminator Brightness.

Subject	B. D.		J. E.		H. K.	
	Time	g_0	Time	g_0	Time	g_0
	0 days	73.2	0-days	61.8	0 days	65.8
	5 "	64.2	2 "	55.7	2 "	69.7
	7 "	73.9	14 "	53.2	16 "	56.6
	33 "	(51.0)*	17 "	54.0	17 "	60.8
	58 "	60.8	21 "	61.6	24 "	69.2
			24 "	60.9		
			28 "	57.6		
			30 "	58.2		
			52 "	62.9		
			56 "	61.9		
Mean		68.0		58.8		64.4
a. d.		5.5		3.0		4.6
Precision		8%		5%		7%

*Reject.

dicated that the respective solutions of both series were approximately isohydrionic and of equal buffer capacity. The osmotic pressure of the solutions was determined by the freezing point depressions. The data for these determinations are given in Table II.

3. *Results*

The corneal scatter kinetics are indicated in Tables III, IV and V and in Figures VII, VIII and IX. Figures VII and VIII show the scatter kinetics for a range of five concentrations of $NaHCO_3$ as well as for a Tuohy corneal lens, which covers only the corneal surface from which it is separated by a thin film or normal lacrimal fluid. The

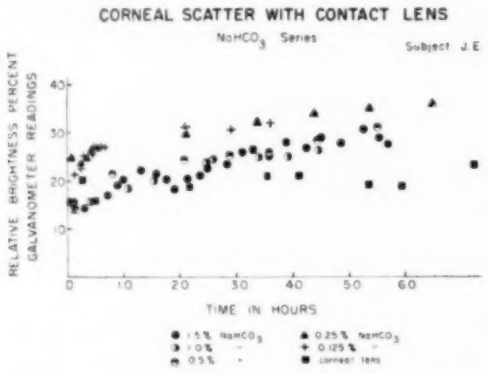


Fig. VII. Corneal scatter with contact lens for subject J. E. with $NaHCO_3$ series.

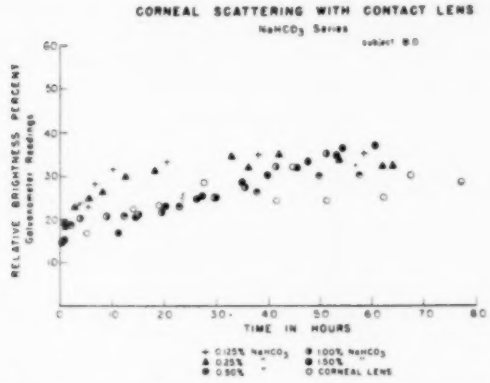


Fig. VIII. Corneal scatter with contact lens for subject B. D. with $NaHCO_3$ series.

results for our subject H.K. are comparable with those for J.E. and are therefore not shown. Figure IX shows the scatter kinetics for a range of three concentrations of Ringer's solution. In Figure VII, the curves for 0.125%, 0.25% and for the corneal lens each represent a single run; those for 0.5% and 1.0% represent two runs, and the 1.5% curve represents five runs. In Figure VIII, those for 0.125%, 0.25%, 0.5% and the corneal lens represent single runs; those for 1.0% and 1.5% represent two runs. In Figure IX each curve represents a single run. Wherever multiple runs are represented, the points as shown were obtained by the method of running averages, each

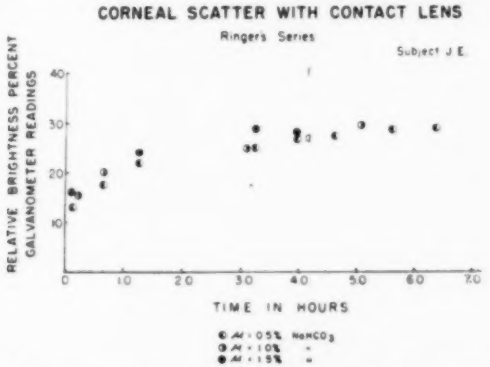


Fig. IX. Corneal scatter with contact lens for subject J. E. with Ringer's series.

point representing the average of three contiguous points in a time sequence covering all the determinations, with time of insertion as zero. The irregularities in the scatter plots indicate largely the day to day fluctuations in photometric conditions.

4. *Conclusions*

Corneal scatter becomes measurable very soon after the insertion of a contact lens. The kinetics are practically independent of the osmotic pressure or buffer capacity over a considerable part of the range of concentrations and solutions employed. Even in the case of the Tuohy corneal lens, which employs no solution and permits a free flow of lacrimal fluid, an initial scatter pattern similar to that of the standard lenses develops. The drop in the scatter patterns for the corneal lenses after three hours of wear is probably an artifact, for our subjects were unable to retain these lenses on the cornea consistently throughout the day, and they had to be repositioned or reinserted repeatedly.*

The particles that produce the diffraction effects also scatter light, and the amount they scatter must be related to the amount they diffract: but these quantities must be so small as compared with the total light scattered, as to fall within the limits of experimental error of the scatter determinations. Possible exceptions may be the hypotonic solutions of concentration less than 0.25%. For these, the diffraction and, therefore, the corresponding scatter may rise rapidly to levels for which a sensible contribution to the total scatter may become evident. A second possibility is that the hydration of the scattering particles proceeds as a two stage process, remaining constant down to some critically low tonicity, and then accelerating. A third possibility is that a separate system of particles is affected at such low tonicities, but little if at all at higher tonicities.

B. *The Kinetics of Diffraction Halo Brightness*

1. *Apparatus*

We were concerned next with measuring the rate at which the observed diffraction haloes wax while contact lenses are worn, and wane after they are removed. After considerable preliminary experimentation with binocular and extinction halo photometry, we designed and developed a monocular halometer which has served acceptably. It is shown in Figure X. The radiating source of this instrument is a General Electric S4, high pressure, mercury vapor lamp (1). The lamp is screened

*This behavior of the corneal lenses is by no means clinically general, for many people wear these lenses throughout a working day without ejection or displacement. At the time of making these measurements, we had not become sufficiently expert in fitting them.

by a cylindrical housing (2) which is ventilated by evacuation through the laboratory vacuum line by means of a copper tube duct (3) and cooled by the blower (4). The lamp housing is perforated anteriorly by a small circular port about 1 cm. in diameter (cut away in the drawing). The light passing through this aperture we call the primary beam

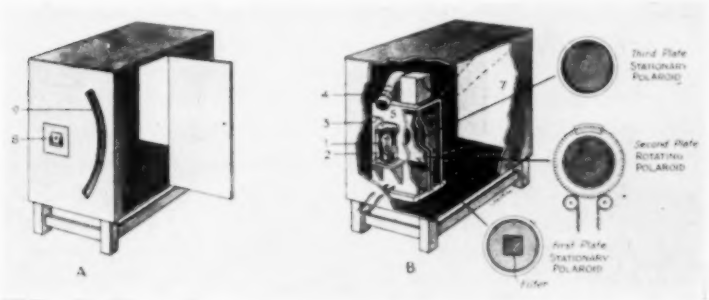


Fig. X. The halometer.

and it, in turn, passes through a Wratten #77 mercury monochromat filter which transmits practically only the green 546 millimicron line, providing a brilliant monochromatic source close to the visibility maximum.

Posteriorly, light passes through a rectangular secondary port (5), then through a Wratten #77 mercury monochromat filter and, finally, through the polaroid system and the rectangular stop (6), as indicated in the diagram. This beam we call the secondary beam. It illuminates a region (7) of the posterior wall of the halometer housing, which is painted white and acts as a diffusing screen placed 40 inches behind the radiating source. The front wall of the halometer housing presents two openings. The first is a small circular aperture of about 1.5 mm. in diameter placed in the path of the primary beam. This we call the primary aperture. The second is an annular aperture (9) subtending a quarter circle at the primary aperture and symmetrically disposed with respect to a horizontal line passing through its center. This we call the secondary aperture. The radius of its inner boundary is such that at a point 16 feet from the halometer along a line through the primary aperture (8), perpendicular to the common plane of both apertures, this inner boundary subtends an angle of 3°. The center of the area, on the posterior wall, illuminated by the secondary beam, subtends the same angle (3°) at the same point (16 feet in front of the primary aperture). This point is

the point of observation and from it the secondary aperture seems to be filled with light, appearing, in fact, like an extended self-luminous source, while light from the primary aperture (8) appears as an intensely luminous point. This luminous point in the primary beam we call the primary source, while the luminous annulus we call the secondary source, or the "comparison arc." The brightness of the comparison arc can be varied by rotating the mobile polaroid which is placed between two fixed polaroid discs whose optic axes are parallel. The rotation is registered on a visible divided circle whose zero meridian lies in a plane of total extinction. By the law of Malus[24] the brightness of the comparison arc relative to its maximum brightness is given by the expression:

$$I_A = I_o' \sin^4 A \qquad (1)$$

where A is the acute angle through which the mobile polaroid would have to be turned to obtain complete extinction. I_o' is the maximum brightness of the comparison arc and I_A is the brightness of the comparison arc at any azimuth of the mobile polaroid. A degrees from the nearest position of total extinction.

The mobile polaroid is manually operated from the point of observation by means of the cord and pulley arrangement indicated. The rotating polaroid disc itself is mounted freely on four radial ball bearings and can be readily and smoothly positioned to within one degree. To a normal observer at the standard observation point, the primary source is seen surrounded by a luminous corona. If the primary source is made of too large a diameter, this corona will extend out to the comparison arc. It is probably the manifestation of a retinal irradiation phenomenon, mainly. The relatively small diameter of the primary aperture actually employed was empirically determined, so as to reduce the apparent radius of this corona and leave the zone contiguous with the inner boundary of the comparison arc in darkness.* It is precisely this zone which is occupied by the halo induced by wearing contact lenses. Since the primary and secondary sources are optically congruent, both arising from the same radiating source, the halo is photometrically related to the comparison arc and correct brightness matches are possible in spite of any fluctuation in the radiating source.[25] The photometric field is far from ideal for a number of reasons. In the first place, the halo is not of uniform brightness. It presents a central maximum, varying continuously to zero on either side. In the second place, the zone at which a match is obtained

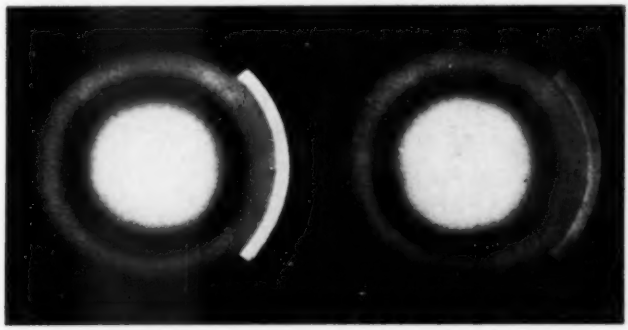
*This reduction in the diameter of the primary aperture results in a small delay in the time required for a developing halo to rise above the perception threshold, as compared with the time required for a larger aperture of about 1 cm. diameter. The delay is of the order of two minutes and is of relatively little importance.

is a matter of personal and subjective choice for each observer. Presumably, that zone is chosen which marks the photopic boundary of the photochromatic interval.[26] Theoretically, as the halo develops in brightness this zone would tend to expand and overlap the comparison arc: but the gradient of brightness distribution is probably so steep at this zone that the lateral shift of the boundary, for the full range of brightness through which the halo passes, is not very great and is subjectively further reduced by the extent of the region of no perceptible difference imposed by the brightness discrimination ratio $\frac{\Delta I}{I}$.[27] In the third place, since the observing eye is the seat of scatter and diffraction losses, the comparison arc itself suffers a reduction in apparent brightness given by $\frac{S}{P} \times 16\%$ where S is the area of the effective zone of the cornea occupied by the diffracting particles and P is the unobstructed remainder of that zone, and some of this diffracted light in the central diffraction corona of the comparison arc itself is added to the halo.[28] Operationally, a reduction in sensitivity therefore results.[29]**

In our instrument the maximum brightness of the comparison arc is such that:

$$R_o = \frac{I_o'}{I_o} \simeq 10^{(-5.5 \pm 0.2)}$$

where R_O is the ratio of the maximum brightness I_o' of the comparison



A B

Fig. XI. Photometric field of the halometer as seen by an observer with a halo

**It is on these grounds that a binocular method recommends itself and should be developed and investigated

arc, to the brightness I_0 of the primary source. This ratio was empirically obtained by exposing an area of the comparison arc equal to that of the primary source, and reducing the apparent brightness of the latter by means of neutral density filters until both sources appeared equally bright to a normal observer at the observation point. The appearance of the entire field to an observer with a halo is shown in Figure XI. In A of this figure the comparison arc is too bright, in B it is close to a match, while when matched the comparison arc becomes indistinguishable from the halo.

2. *Procedure*

A match is, of course, obtainable in each of four quadrants and, in actual practice, nine matches are obtained, three in one quadrant and two in each of the remaining three. The mean of these nine readings is taken as a single determination, and the precision of this mean is of the order of 5 per cent. When the rate of development of the halo is high, as when certain hypotonic solutions are employed, a determination may have to consist of but two readings in a single quadrant with some reduction in precision and accuracy.

The reliability of the system of polaroids was determined by calibrating the halometer. The detector of our microphotometer was pointed at the comparison arc and the galvanometer read at 10° intervals, as the mobile polaroid was turned through a complete revolution. Figure XII is a plot of the calibration curve so obtained against the theoretical curve computed from equation (1). The continuous line represents the theoretical curve and the open circles the observed values. The deviations are negligible. Each observer was careful to make the photometric matches at the center of the comparison arc, since extinction did not occur simultaneously over the entire arc but progressed continuously along it.

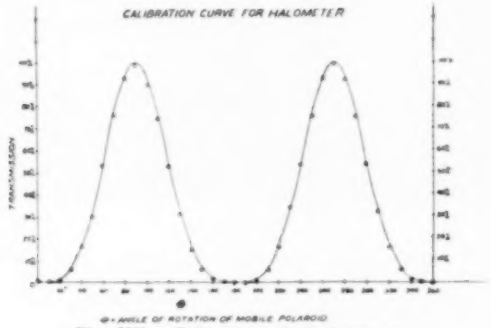


Fig. XII. Calibration of the halometer.

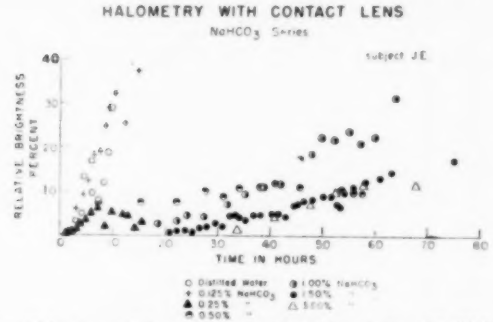


Fig. XIII. Halometry with contact lens for subject J. E. with $NaHCO_3$ series

Usually, a day's work for a single subject consisted of alternate photometer and halometer measurements at about one-half hour intervals. The intense light of the photometer rendered a period of about twenty minutes of dark adaptation necessary, before a halometer reading was possible. As a matter of uniformity, a routine procedure of adaptation was followed. Dark adaptation was permitted to continue until the subject was able to perceive the comparison arc when its brightness had been reduced to a level three log units below its maximum while the

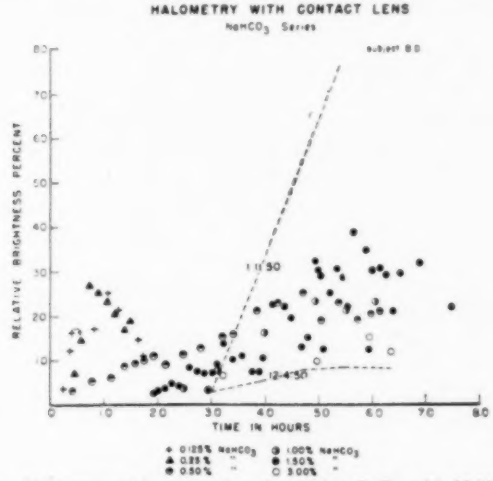


Fig. XIV. Halometry with contact lens for subject B. D. with $NaHCO_3$ series

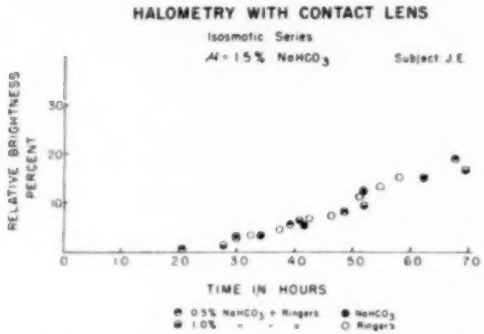


Fig. XV. Halometry with contact lens for subject J. E. with solutions isosmotic with 1.5% $NaHCO_3$.

primary source, reduced four log units, was fixed. At this point the primary source was exposed at full brightness, fixation was shifted to the inner boundary of the comparison arc, and its brightness was increased to 94 per cent of its maximum. Fixation here was maintained for two minutes, and the matching then begun. These levels of adaptation were arbitrarily chosen at 10° from total extinction and 10° from maximum transmission, respectively. Other reasonable levels might have served equally well, so long as the procedure were kept uniform.

3. *Results*

The obtained curves for J. E. and H. K. are comparable. Those for J. E. will serve as typical. The method of running averages by threes was employed for those curves that represent multiple runs. In Figure

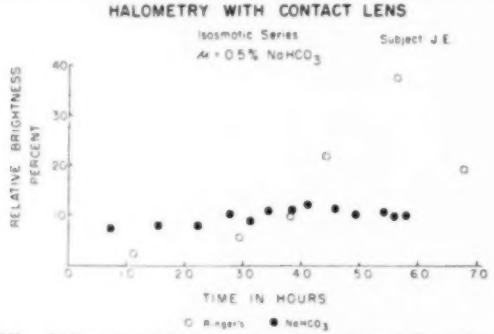


Fig. XVI. Halometry with contact lens for subject J. E. with solutions isosmotic with 0.5% $NaHCO_3$.

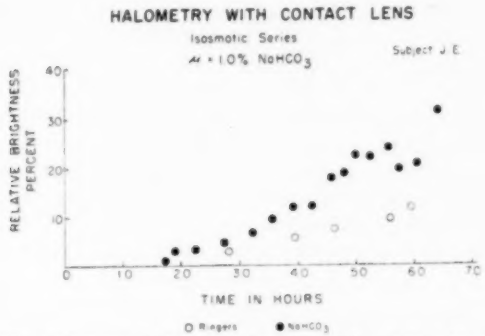


Fig. XVII. Halometry with contact lens for subject J. E. with solutions isosmotic with 1.0% $NaHCO_3$.

XIII, the curves for distilled water, 0.125%, 0.25% and 3.00% represent a single run. The 0.5% curve represents two runs, the 1.0% curve three runs and the 1.5% curve six runs.

In Figure XIV the curves for 0.125%, 0.25% and 3.0% represent single runs. Those for 0.5% and 1.0% represent two runs while the 1.5% curve represents nine runs. The scatter of the points for this solution is quite wide and unlike that of the corresponding curve for J. E. In Figure XV all curves represent single runs except the curve for Ringer's which represents two runs. In Figures XVI and XVII all curves represent single runs.

4. *Conclusions*

The early appearance of haloes for test solutions of lowest tonicity and their rapid increase in halo brightness as indicated in Figure XIII and XIV accords well with the osmotic pressure hypothesis, so far as the corneal elements responsible for haloes are concerned. The increasing delay with increasing concentration is also in agreement.

The congruence of the curves of Figure XV,* all of which represent the effect of solutions of equal osmotic pressure but of markedly different buffer capacities and presumably CO_2 uptakes, strongly supports this hypothesis and weakens the chloride shift hypothesis.

The rates with which haloes develop for the various solutions, however, are not in strict accord with the osmotic pressure hypothesis. In Figure XIII the curves for 0.25% and 0.50% $NaHCO_3$ are unexpectedly low, while those for 1.0% $NaHCO_3$, still hypotonic, are high.

*In the case of Ringer's isosmotic with 1.5% $NaHCO_3$, the curves for B. D. and H. K. are considerably depressed. The reason is not clear at present.

The curves of Figure XIV show a general similarity with this pattern and those of Figures XVI and XVII are not in agreement at all with this hypothesis. The wide scatter for the 1.5% $NaHCO_3$ in Figure XIV is probably due to a process of adaptation in this subject, B. D. The two dotted lines that appear on this plot are dated to indicate the difference in rates for precisely the same lens and solution, approximately one year apart. Plots on intermediate dates show generally intermediate rates.

C. *The Determination of the Gradient of Population Density of Diffracting Particles by Halometry*

This determination should test the invasion hypothesis.

1. *Apparatus*

The halometer and an iris diaphragm with a minimum aperture diameter of 1.5 mm. were employed in the experiment.

2. *Procedure*

A halo was permitted to develop with a contact lens in place. The subject matched the halo brightness with the halometer. The aperture was then increased and a match again obtained.

The procedure was repeated with the addition of neutral density filters chosen to maintain the total energy passing through the aperture constant and equal to that passing through the smallest aperture.

3. *Results*

For all our subjects, for every size aperture, with or without compensating filters, the relative brightness remained constant within the precision of the method.

4. *Conclusion*

The diffracting particles responsible for the haloes are uniformly distributed. If they were not but became more numerous centrifugally, then the halo would become brighter than the comparison arc, since the area of unobstructed pupil would increase more slowly than the number of effective diffracting particles; and while the brightness of the halo is proportional to the total number of effective particles, that of the comparison arc is proportional to the total unobstructed area of the pupil. The results of this experiment are, therefore, opposed to the invasion hypothesis and in accord with the osmotic pressure hypothesis.*

*Part II of this paper will appear in the May, 1952, issue

A CASE OF TRANSIENT MYOPIA DUE TO INGESTION OF SULFA*

Richard A. Kramb†
Van Nuys, California

Although over 100 cases of transient myopia due to sulfa drugs have been reported within the past 10 years, the following is presented to emphasize the rapidity of onset and decrease of the myopia, and the small dose of sulfa necessary to elicit this response.

CASE HISTORY

Mrs. R. S., age 41, a nurse, reported that late in the evening of February 6, 1952, she noticed that distant objects were very blurred, and that she had a headache and general discomfort. The next morning the headache persisted and the distance vision was still blurred. She reported that she had been taking care of her daughter who had influenza and that on the previous day she had taken one of the sulfa pills (tricombisul, .5 gm.), prescribed for her daughter. Further questioning revealed that 2 months earlier she had taken about 10 pills of tricombisul (.5 gm.), but that no side effects appeared at that time. Outside of a bad cold two months ago for which the sulfa was prescribed she had enjoyed excellent health. No apparent systemic disorders were present.

At the time of examination the patient was quite alarmed and nervous over the state of her vision. She had enjoyed 20/15 acuity without glasses all her life and in a matter of hours the acuity had dropped to 20/200. The only comforting thought was that she could read and see everything clearly within arm's length.

Visual acuity—O.U. Over 20/200. O.D. Over 20/200. O.S. Over 20/200. Pinhole Acuity 20/50.

EXTERNAL EXAMINATION

Slight injection of conjunctiva and slight edema of the upper lid.‡ Anterior chamber clear, cornea clear, pupil reaction normal to direct and consensual light stimulation and to accommodation, rotations good.

FUNDUS

Media clear, disc clear, no abnormal cupping, A-V ratio 2-3 with

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†Optometrist.

‡Similar edema reported by Hornbagen in a case of sulfanilamide myopia. (A. J. Oph. 1941).

no sheathing or edema. In general, the picture of a healthy fundus.

REFRACTION

	Feb. 7, 1952	Feb. 9, 1952
Ophthalmometer.	O.D. 42.00 X 180 42.50 X 90 O.S. 42.00 X 180 42.50 X 90	Same as Feb. 7
Static Retinoscopy.	O.D. —2.50 + .50 X 90 O.S. —2.50 + .50 X 90	O.D. —3.00 O.S. —3.00
Subjective.	O.D. —4.25 20/30 O.S. —3.50 20/30	O.D. —4.50 20/25 O.S. —4.25 20/25
Phoria at 6 meters.	6 eso	4 eso
Adduction.	8/3	8/4
Abduction.	3/1	4/2
Vertical Phoria.	Ortho	Ortho
Phorias at 16".	3 eso	2 eso
Posit. Fus. Conv..	8/24/16	8/24/16
Neg. Fus. Conv..	X/24/12	X/20/10
Minus lens to Blur.	—.75	—1.00
Plus lens to Blur.	+1.00	+1.00

The patient was told that the myopia was probably caused by a reaction from the sulfa and that it would probably disappear within a week to 10 days. A pair of —4.00 D.S. was loaned to the patient with instructions to note any change of acuity either through the lenses or without the lenses. The family physician was informed of the visual condition and of the diagnosis and prognosis.

The patient was re-examined on February 9, 1952, and the findings are presented above. The discomfort had decreased and the headache had disappeared.

On the evening of February 10, the patient reported that objects were blurred through the —4.00 lenses and that the naked acuity was clearing. By the morning of the 11th (5 days after onset) the —4.00 was removed and the patient reported her visual acuity again normal. During this period considerable discomfort was evident in the form of headaches and some general nausea.

The patient was examined for a third time on February 18 and the following found:

Visual Acuity O.U. 20/15 O.D. 20/15 O.S. 20/15

EXTERNAL EXAMINATION

Clear anterior chamber, pupils normal to light and accommodation, no edema.

FUNDUS

Clear media, disc clear, healthy appearance.

REFRACTION

Ophthalmometer.	O.D. 42.00 X 180 42.50 X 90	O.S. 42.00 X 180 42.50 X 90
Static Retinoscopy.	O.D. Pl. + .50 X 90 O.S. Pl. + .25 X 90	

Subjective. O.D. Plano
O.S. + .25
Phoria at 6 meters. Ortho
Adduction. 18/28/12
Abduction. 9/3
Vertical Phoria. Ortho
Phoria at 16". ½ exo
Gradient. + 1.00/5 exo
Posit. Fus. Conv.. 14/28/14
Neg. Fus. Conv.. 10/28/6
Amp. of Acc.. 6 D. Push up.
Minus Lens to blur. —1.00
Plus lens to blur. + 2.25

DISCUSSION

The patient here reported showed a number of the classical manifestations of sulfanilamide myopia as summarized by Duke-Elder.

The reaction generally occurs after a sensitivity has been set up through previous dosage. It is of sudden onset and accompanied by discomfort. The duration is from 2 to 10 days. In this case the discomfort disappeared after the myopia had reached its apparent peak and again reappeared when the myopia was decreasing. The acuity can be corrected during the myopic stage by minus lenses. The mechanism for the production of the transient myopia is not clear. The interesting point about this case is the small dose which set off the intense reaction.

SUMMARY OF GRAPHIC FINDINGS

1. ACA ratio remained essentially the same.
2. N.F.R. line and the P.F.R. line decreased and moved toward the Donders Line. i.e., Zone was reduced in breadth.
3. Phoria line (slope constant) moved toward the esophoric side.
4. Accommodative amplitude not measured during the first two examinations. It is obvious that this should have been taken and should be done on any future cases.

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SIMPLE TARGETS FOR INVESTIGATING BINOCULAR VISION IN CHILDREN*

Marion Rush Stoll†
Charlotte, North Carolina

The usual tests frequently fail to provide satisfactory proof of stable binocular vision in young children. Demonstration of depth perception in doubtful cases may reasonably be interpreted to mean not only that the child can fixate binocularly but that he does so habitually. Such proof can sometimes be obtained with the synoptophore or other binocular apparatus, but the test described below has proved much easier to use with many children, because it permits them to substitute pointing for verbal responses.

Configurations are drawn in red and green on 3x5 cards and viewed through red-green spectacles as described in an earlier paper.[1] Preliminary to the depth test, other cards are presented with simple drawings which the child can name or in which he may point to details named by the examiner. I use the following four pictures: a pair of glasses drawn in green; a house drawn in red; a cup in green and a fork in red; and a scene with a wagon in red, a cat in green and other details in the two colors. Children are encouraged to touch the pictures named if they show any tendency to do so.

The depth test configurations are presented next without interruption. These are pictured in Figures 1, 2 and 3. The oblique lines in Figure 3 frequently confuse very young children, but with older ones this figure may seem easiest of the three, perhaps because of the superimposition of details. It has the advantage of not giving a different effect when turned upside down as do the other two. This provides an additional check when guessing is suspected.

The following brief case history indicates the usefulness of the test.[2] A little girl was brought in at the age of 2½ years with a history of squint of 3 months' duration. Right esotropia of 40 prism diopters was measured. Glasses and use of atropine did not effect improvement and surgery was resorted to a year later. After this the eyes appeared straight but no subjective test was satisfactory at first. The child had

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†Optometrist, Ph.D.

just passed her fourth birthday when we succeeded in coaxing her into a trial at the synoptophore.

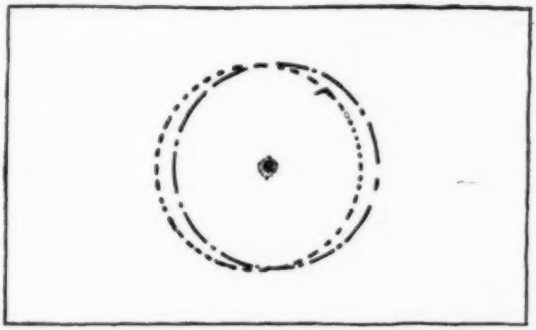

Fig. 1. The two circles are drawn in red (— . — .) and green (. . . . .), respectively, and the center is represented by a red disc surrounded by a green diamond. When viewed through red-green spectacles with the red glass over the right eye, the circle should appear to be in front of the card. When the card is reversed, the circle recedes beyond the card but this may be interpreted as the center coming forward.

Binocular fixation was indicated with 10 prism diopters base-in, and fusion targets were fixated while the prism was reduced to zero. No satisfactory evidence of depth perception was obtained. At near, the child pointed to the dots of the Worth four dot test fairly but she did not name colors or report the number of dots seen.

With the pictures described above she responded with confidence. When Figure 1 was presented and she was asked whether the circle or the center seemed to come out of the card and closer to her, she

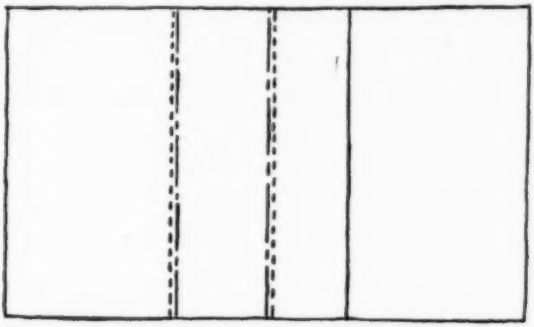

Fig. 2. Red and green are superimposed in the solid line, and represented as in Fig. 1 elsewhere. The left line appears to come forward when viewed through red-green spectacles with the red lens over the right eye. The center line is seen back of the card but it seems best to ignore this detail in testing your children.

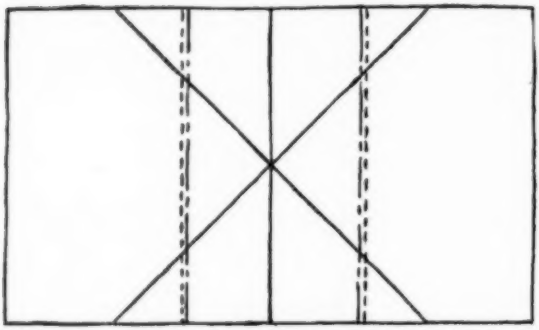

Fig. 3. Red and green are represented as Figs. 1 and 2. Viewed in the same way, the left line appears to be in front of the cross, the right line in back of the cross. Reversing the card does not change this effect.

immediately indicated the circle, at first reaching as if to pick up the circle about an inch in front of the card. When the card was reversed she pointed to the center, and she did equally well with Figure 2. Figure 3 obviously presented more difficulty: it was not clear that she was indicating the straight line rather than the oblique, but she did designate the correct side of the figure each time.

This demonstration of depth recognition confirmed the impression that she was using the two eyes together and justified dismissal until she should return for a three months' check-up.

116 EAST SIXTH STREET

CHARLOTTE, NORTH CAROLINA.

REFERENCES

[1]Stoll, M. R. Adaptations of Luneburg's Design for Demonstrating the Geometry of Visual Space. Amer. J. Ophthal., 1950, 33:1919-1920.

[2]The observations were made on a child under the care of an ophthalmologist, who permitted this abstract from the record. The author's responsibility was limited to the test made at age 4.

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SOUTH AFRICAN OPTOMETRISTS IN LEGISLATIVE FIGHT

South African optometrists have made excellent progress in the last several decades. The profession from Capetown to Johannesburg and Pretoria is well organized and enjoys proper public respect. The majority of optometrists in South Africa are well qualified to do their health work having had professional training either in British optometric schools or in the optometric college at Capetown. These optometrists practice much as do optometrists elsewhere in the British Commonwealth except they largely rely upon U. S. A. sources for the materials they dispense.

Many British colonies and segments of the Commonwealth have acts regulating the practice of optometry, but South Africa does not enjoy such a law. At present the South African Minister of Health has proposed such legislation. His proposals, however, do not meet the

approval of South African optometrists. He has proposed legislation giving his office the power to define the extent and scope of optometric practice, and his current proposal further requires that patients seeking the services of an optometrist for a refraction must first secure a referral slip from a physician.

South African optometrists insist that the scope of optometric practice be defined in the law itself, just as it is in other laws regulating optometry throughout the Commonwealth and in the United States. South African optometrists practice as do optometrists everywhere. They limit their work to the examination and refraction of the eye and the correction of ocular problems by means of spectacles, orthoptic procedures or contact lenses. Ocular pathologic cases in South Africa are referred to ophthalmologists. South African optometrists are willing to thus define the scope of optometric practice, but for their present and future security, they want the extent and scope of this practice clearly outlined in the law itself.

They are naturally unwilling to accept the provision of a required referral from a physician. They claim properly that this would be an unwarranted interference in the personal liberty of the patient and the optometrist, to say nothing of being a waste of time and effort on the part of both the patient and the physician.

It is interesting to United States optometrists to recall that the present Compulsory Health Insurance bill now before the Congress in Washington has a similar provision. This bill, which has the complete support of the administration, makes a similar requirement that all auxiliary health work (including refractions) be done only on a referral basis through a physician.

At present this Compulsory Health Insurance bill is dormant inasmuch as the administration lacks the votes in either the Upper or Lower House to adopt it. Present plans call for bringing the measure out for approval in 1953 if the proponents of this measure are still in power.

We believe that adverse public opinion aided by professional condemnation of the measure in the U. S. A. is strong enough to defeat or drastically amend such a proposal here. We hope this is also true with the legislation now confronting our South African colleagues and we wish them success in the vigorous fight they are waging in the profession's behalf.

CAREL C. KOCH

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

INTERPROFESSIONAL COMMITTEE IN MINNESOTA

Dr. Frank Adair, ophthalmologist of St. Paul, was elected chairman of the Minnesota Interprofessional Committee on Eye Care at the March 24 meeting of the committee. Otto G. Batzli, Walman Optical Company, Minneapolis, was elected vice chairman, and Dr. R. O. Lindquist, optometrist of Minneapolis, was elected secretary. The other members of the committee are James F. Brusegard, M.D., Red Wing, Minnesota, Jack Coffey, Bausch and Lomb Optical Company, Minneapolis, Minnesota, Rudolph Ehrenberg, O.D., Granite Falls, Minnesota, John H. Peterson, M.D., Duluth, Minnesota, Fred H. Rohlin, O.D., Marshall, Minnesota, and Arthur Williams, St. Paul, Minnesota.

The ophthalmologists on the committee have been appointed to serve by the Minnesota Academy of Ophthalmology. The optometrists have been appointed by the Minnesota State Optometric Association. The members representing opticianry have been appointed by the Optical Wholesalers National Association and by the Independent Optical Wholesalers Association. The committee will meet periodically and direct its efforts towards better cooperation among those serving the public in the field of eye care in the interest of the patient. Dr. Avery D. Prangen, Section on Ophthalmology, Mayo Clinic, Rochester, Minnesota, reviewed the work of the National Interprofessional Committee on Eye Care of which he is chairman.

CAMPUS NEWS

Dean of the new *University of Houston College of Optometry* when it opens next Fall will be Dr. Charles R. Stewart, now assistant professor of optometry at *The Ohio State University*. Dr. Stewart, the first faculty member appointed for the new College, attended North Texas State College and Oklahoma University, received his B.S. in Optometry and M.S. in Physiological Optics from The Ohio State University College of Optometry, and a Ph.D. in Physiological Optics in 1951 from Ohio. He is 33, married and has three children; and was an officer in World War II. At present, he belongs to Sigma Xi, the Ohio State Optometric Association, American Optometric Associa-

tion, Optical Society of America, Central Ohio Academy of Optometry, Beta Sigma Kappa, Advisory Committee on Vision of the Ohio State Department of Health, and the American Academy of Optometry.

Recent honors bestowed on the faculty of *Chicago College of Optometry* include an honorary life fellowship in Tomb & Key Fraternity to Dr. Z. J. B. Schoen, graduate studies director, and a Fellowship in the Distinguished Service Foundation of Optometry to Dr. Eugene Freeman, Dean.

The Optometry Alumni Association of the *University of California College of Optometry* has voted to raise funds for a portrait of Professor Emeritus Ralph S. Minor, first dean of U. C. School of Optometry. The portrait will be hung in the optometry library. Dr. Minor retired from the faculty in 1946.

The cornerstone of *Pacific University College of Optometry's* new Jefferson Hall was laid Tuesday, March 4, 1952. Records of important dates in the history of the College of Optometry were placed in copper encasements behind the cornerstone, and a brief ceremony held under the direction of Dr. D. T. Jans, chairman of the optometry staff. Dr. Walter C. Giersbach, President of Pacific University, spoke on "Dr. G. Orlo Jefferson—the Man," tracing the career of this physician who contributed the major portion of the building funds.

Los Angeles College of Optometry is offering a very comprehensive Summer Session May 26 to June 6, 1952. Binocular vision, depth perception, perimetry, embryology, color vision, psychosomatic disorders of the eye and industrial vision are among the topics to be covered in 46 lectures by 15 staff members and one guest speaker, Dr. Victor E. Hall, M.D., professor of physiology, Medical School, University of California, Los Angeles. Complete information on this two-week intensive session may be obtained by writing Dr. Monroe J. Hirsch, Director of Summer Sessions, Los Angeles College of Optometry, 950 West Jefferson Boulevard, Los Angeles 7, California.

At *Northern Illinois College of Optometry* Commander R. Rosswell Sullivan, head of the Optometry Bureau of Medicine and Surgery Section, U. S. N., was a guest speaker. Commander Sullivan developed for the students the history of optometry in the armed services.

Two summer workshops will be held for practicing optometrists at N. I. C. O. this year. A four-day occupational vision seminar starts July 14. From July 19-23 refresher courses in practical optometry are being offered.

INTERNATIONAL CONGRESS OF OPHTHALMOLOGY TO MEET IN NEW YORK

For the first time in 78 years, the International Congress of Ophthalmology will meet in the United States, in New York City, the week beginning September 12, 1954. This group, dedicated to the promotion of the science of ophthalmology throughout the world, last met in this country in 1876 in New York City and first met in Brussels in 1857. The Congress meets every four years, except for war interruptions. The 1954 meeting will be the Seventeenth Congress.

The invitation to meet in New York City was extended jointly by the American Ophthalmological Society, the Section on Ophthalmology of the American Medical Association, the Association for Research in Ophthalmology and the American Academy of Ophthalmology and Otolaryngology. Dr. William L. Benedict, Secretary General of the Congress, 100 1st Avenue Building, Rochester, Minnesota, is handling Congress correspondence for the coming meeting.

NEWS BRIEFS

In May Dr. E. J. Margaretten will be presented with a plaque by the New York Academy of Optometry in recognition of outstanding service to optometry. The award will be made at the Columbia University School of Optometry Alumni Reunion, May 17 in New York City. The plaque has not been awarded since 1946. Dr. Margaretten is on the staff of *Columbia University School of Optometry*. . . . An annual achievement award of $100.00 has been established at *Northern Illinois College of Optometry* by Dr. Phillip Jackman, Hackensack, New Jersey. The award will be made each year to an outstanding fourth year student. Dr. Jackman is an alumnus of N. I. C. O., Class of 1926. . . . A new directory is being prepared by the Aniseikonic Forum of aniseikonic practitioners. . . . The California Optometric Association is conducting, through West-Marquis, Inc., a study of public relations in optometry to determine what information or misinformation the public has about the profession. The survey will take about 60 days, and is expected to produce guides for future public relations activities of the association. . . . American Optical Company has announced a new peep-hole, post-operative cataract lens which will allow a patient to see immediately following a cataract operation. Designed by Dr. Otis R. Wolfe, Marshalltown, Iowa, the lens is used to allay anxiety of the patient over his ability to see after the operation. The glass lens, $\frac{3}{8}$ inch in diameter, is cemented into an opaque plastic shield covering the eye, and possesses the high power characteristic of the conventional

cataract lenses. The lens, according to Dr. Wolfe, protects the eye by restricting the passage of light and preventing movement prejudicial to healing. It does not replace the conventional type cataract lens.

NEW INSTRUMENTS

American Optical Company has announced a new series of ophthalmic diagnostic instruments to be known as the A0 Ful-Vue Series. Included will be ophthalmoscopes and retinoscopes. All the diagnostic instrument heads are designed for one-hand operation and are interchangeable on either a medium or large size battery handle. In the ophthalmoscope, all adjustments are made with the thumb or forefinger, leaving one hand free. A five position aperture selector provides for instant selection of normal, pinhole, slit, yellow or red-free apertures. Twenty-three precision lenses from —25 D. to + 40 D. are located in a single rotating disc.

The new A0 retinoscope may be changed from static to dynamic retinoscopy by uncovering the built-in transilluminated target. All the new instruments have a thumb-controlled rheostat for increasing or decreasing light intensity.

SEMINARS AND MEETINGS

May. The Colorado Optometric Association will hold its annual Spring meeting May 22-24, in Gunnison, Colorado.

June. The 55th Annual A. O. A. Congress at Miami Beach, Florida, June 8-11, will feature on its educational program a panel headed by Dr. Darell Boyd Harmon on factors influencing achievement in school. Dr. John C. Neill, Philadelphia, will speak Sunday afternoon on "Optometric First Aid in Atomic Bombing."

November. Rutgers University will hold its Second Annual Conference on Occupational Vision in Atlantic City, New Jersey, on November 13, 14, 1952. This year's conference will feature work shops in eye safety and conservation of vision, with the emphasis on visual efficiency.

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Dual Purpose — glare protection and eye correction in the same lens	**Non-habit-forming** — tests prove that patients wear Soft-Lite with more comfort
Neutral Transmission — color values of entire spectrum unaltered, as with white lenses	**Tenacity of Tint** — modern Soft-Lite is fade-resistant and uniform in color
White Segments — absorption for distance with white transmission at near point	**Comparator Tested** — like white, Soft-Lite does not fluoresce in the Comparator

2 Since patients differ in light sensitivity, as well as occupation, today's refracting routine should include the use of glare symptom questions and Trial Case Accessory, to assure maximum benefits from the Rx.

3 The different and more costly ingredients in Soft-Lite Lenses make them non-habit-forming and ideal for light-sensitive patients. The difference is instantly identifiable in the Comparator. When prescribing for the common complaint of glare, instead of "tint" specify genuine Soft-Lite. Available in all Bausch & Lomb lens forms.

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The guest lecturer will be:

Dr. Victor Hall, Professor of Physiology, School of Medicine, University of California at Los Angeles, whose theme will be "The Psychosomatic Aspects of Optometry."

The faculty and staff of the college will participate extensively in the course, lecturing on the subjects with which they are particularly concerned.

Enrollment may be for one or for both weeks of the course. Tuition will be $25.00 per week.

For further information write to:
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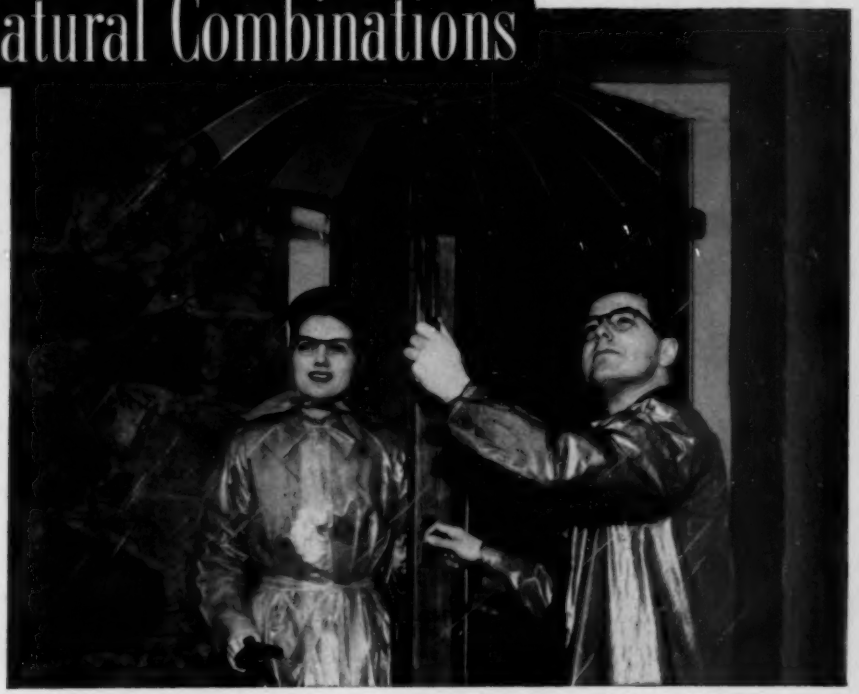

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